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HANDY BOOK

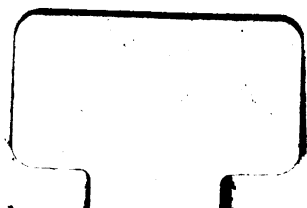
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ON THE

ENGINEER DEPARTMENT

UNITED STATES NAVY

1915



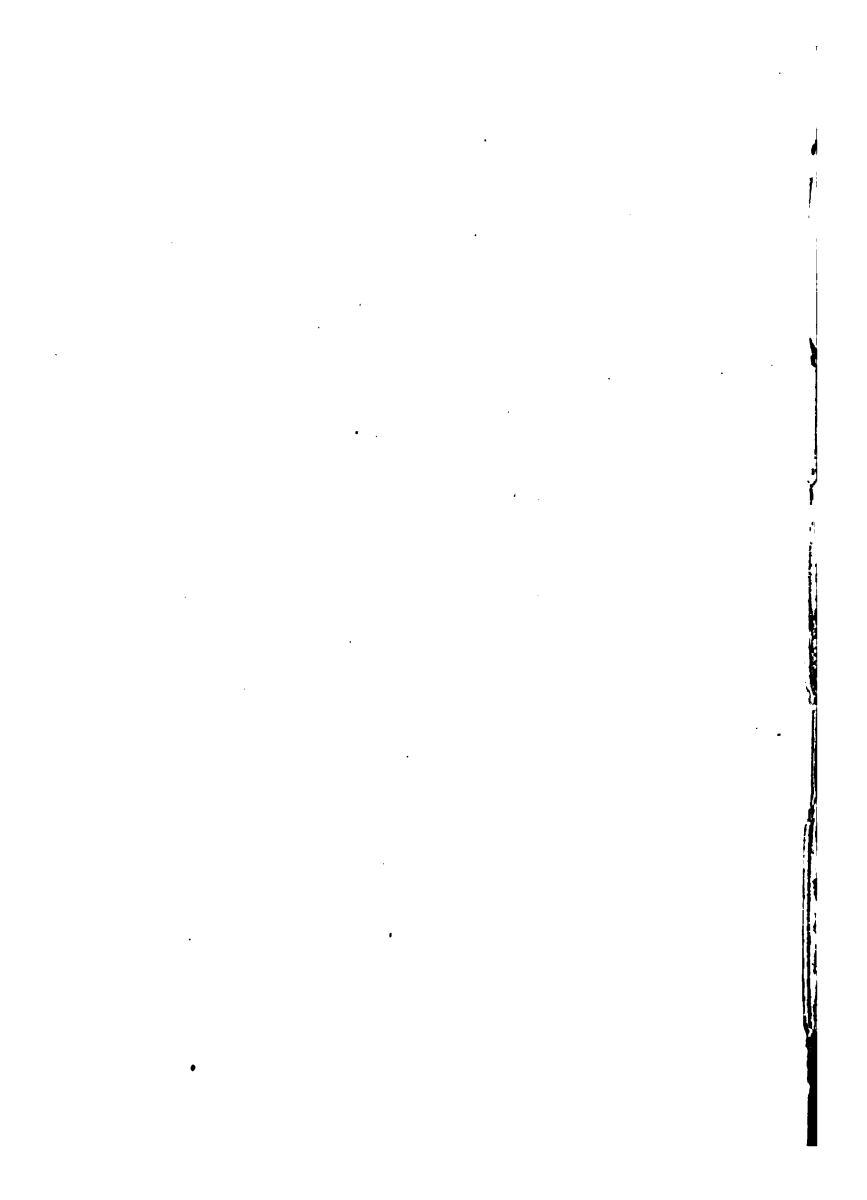
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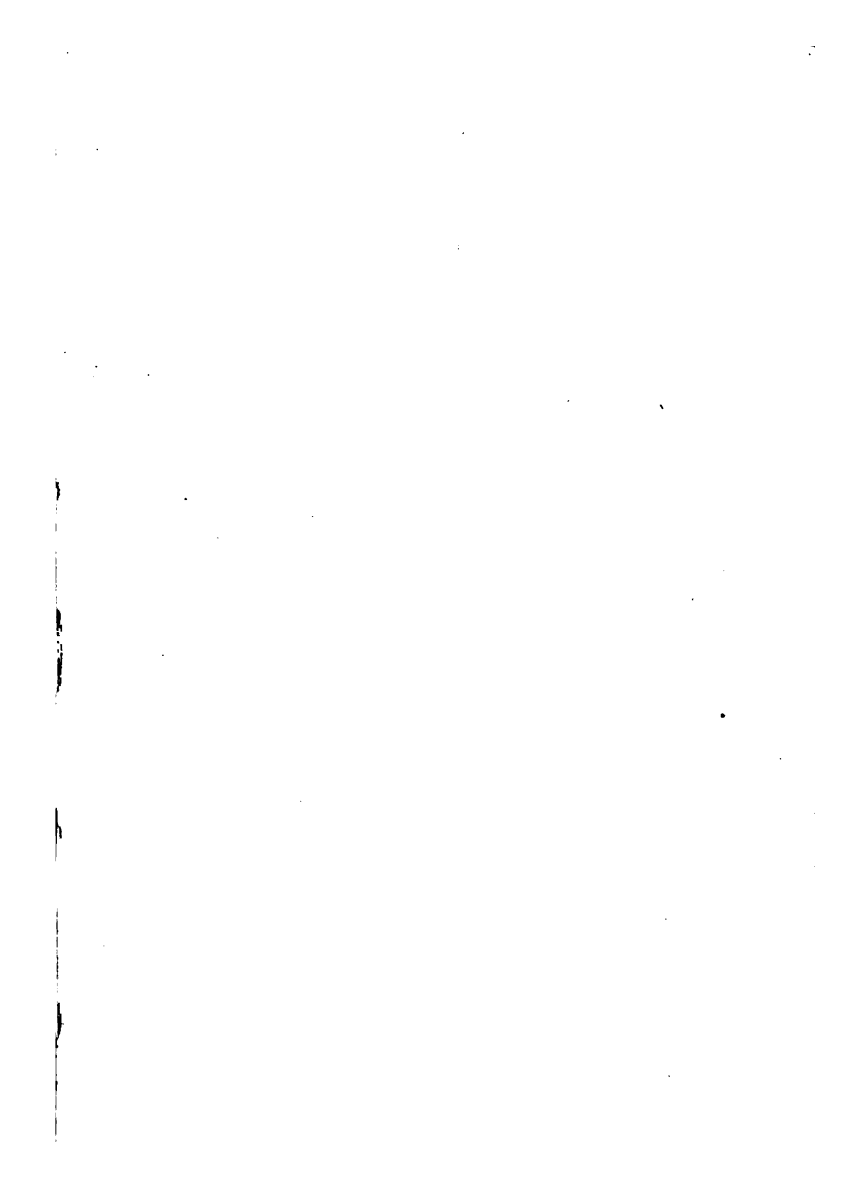
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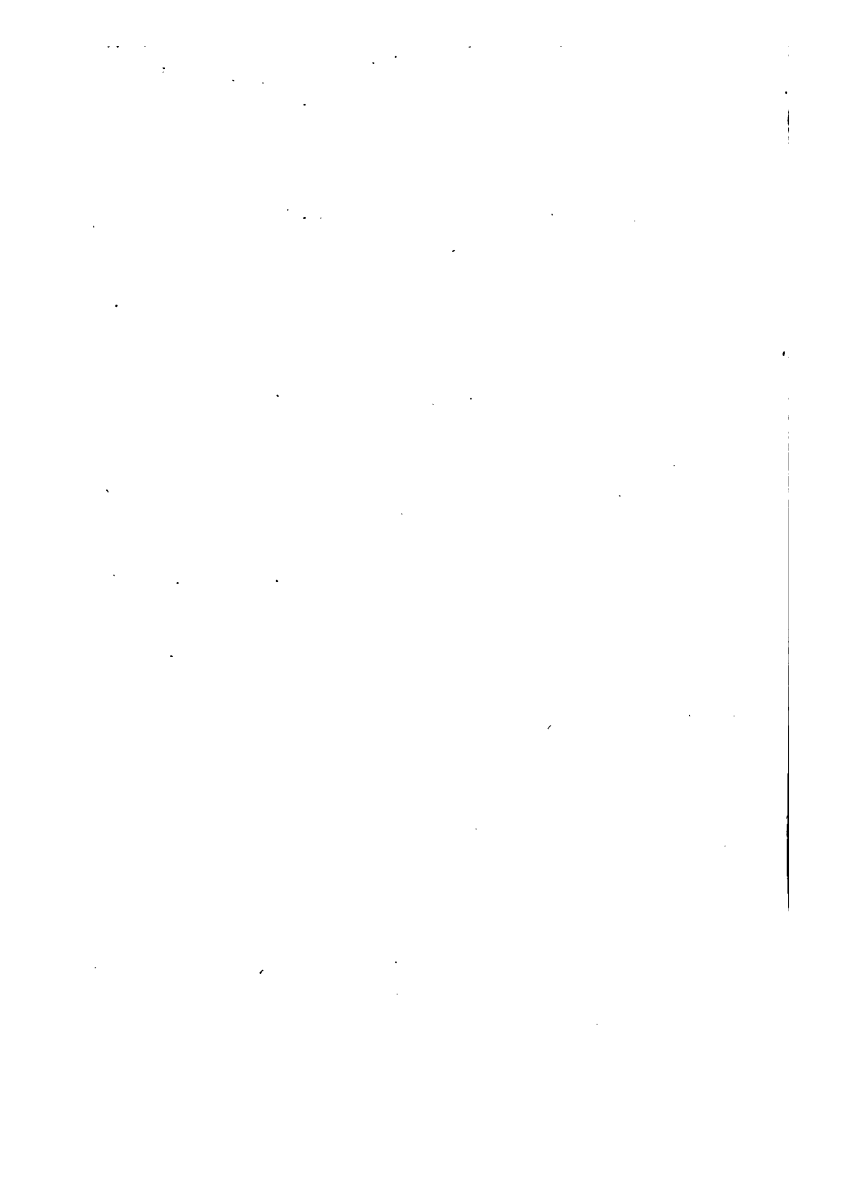
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HANDY BOOK

for the AID AND INSTRUCTION *of the*
ENLISTED MEN IN THE
ENGINEER DEPARTMENT
UNITED STATES NAVY

PREPARED BY *Richardson*
Midshipman BRUCE R. WARE
U. S. Navy =
1908

REVISED BY
Lieutenant (J. G.) BRUCE R. WARE
U. S. Navy
1914



WASHINGTON
GOVERNMENT PRINTING OFFICE
1915

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FOREWORD.

The fighting efficiency of every ship depends on her ability to make the most hits in the shortest possible time with the least expenditure of ammunition, and to make the required number of revolutions with a minimum expenditure of fuel, lubricating oil, and water without breakdown. To make this possible, in time of action each man, whatever his rating, must be constantly alert and at all times doing his duty, no matter how slight the duty is nor where it is performed. From knowledge, power; from practice, expert performance; and from these, victory.

BRUCE R. WARE.

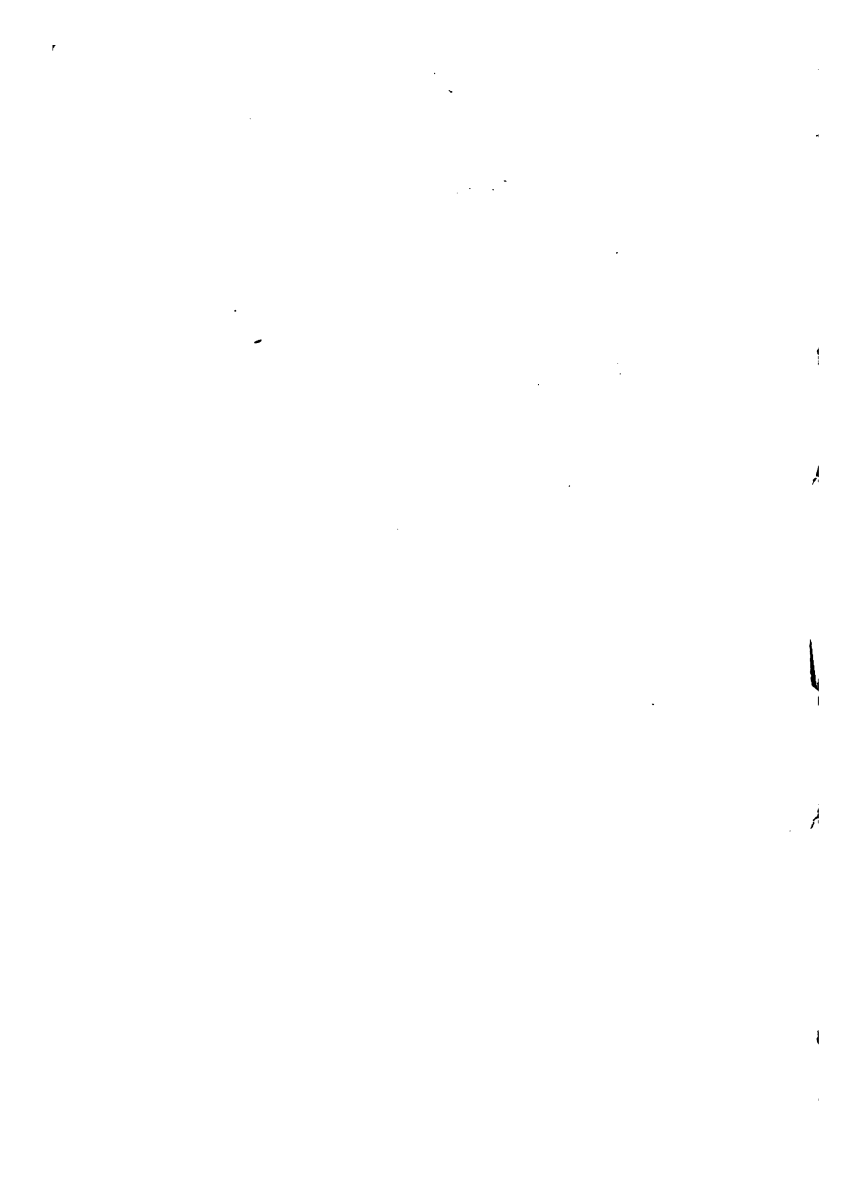
GIVING ENLISTED MEN A GREAT OPPORTUNITY.

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The following amendment to the naval appropriation bill was agreed to in conference and will consequently become law. It reads as follows:

“Providing that there may be appointed annually from the enlisted men of the Navy who are citizens of the United States and not more than twenty years of age, and who have served not less than one year, fifteen enlisted men to the United States Naval Academy, to be selected in the order of merit by competitive examinations prescribed by the Secretary of the Navy, and such men so selected are required to pass the physical and mental examination now required by law for entrance to the Naval Academy.”

This is a splendid opportunity for young men who enlist in the Navy to satisfy their ambition in the endeavor to be one of the chosen few to go to the Naval Academy and, if it is in them, later in life reach the highest position attainable in that service. This recent act of Congress will beyond a doubt encourage enlistments and induce young men of superior intelligence to remain in the service longer than heretofore, with the hope of reaching the Naval Academy and afterwards the quarter-deck of a warship.—
Naval Institute, July, 1914.

(See Appendix I, p. 171.)



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INTRODUCTION.

The object of the writer in preparing this book is to provide a brief, practical aid for the men composing the Engineer Department of a seagoing ship. No attempt has been made to go deeply into the study of steam engineering, the particular reason being to instruct and help the men in the line of promotion and to increase their efficiency in the various ratings.

The writer's aim has been to collect in a handy form a few important principles that the men can obtain at the least expense. Considering the fact that there are books of this nature for the deck force, it seems equally fair to provide similar ones for the men of the engineer force.

BRUCE R. WARE,
Midshipman, United States Navy.

U. S. S. WEST VIRGINIA,
October, 1908.

REVISION.

The revision of this Handy Book was prompted by a desire to keep it up to date in step with the advancement of engineering; to meet more fully the requirements of General Order No. 63, "Instruction on Board Ship."

BRUCE R. WARE,
Lieutenant, Junior Grade, United States Navy.

POST GRADUATE DEPARTMENT,
Navy Yard, New York, September 1, 1914.

PREFACE.

[An extract from General Order No. 63, Navy Department, Dec. 16, 1913.]

INSTRUCTION ON BOARD SHIP.

1. The following plan for the instruction of enlisted men, petty officers, and warrant officers of the Navy serving on board ship will be put into effect on January 1, 1914:

THE SUBJECTS THAT EVERY MAN ON BOARD SHIP SHOULD KNOW.

17. All men on board ship, of whatever rating, will be instructed in and will be required to prove their knowledge of—

A. The necessity of realizing the twofold nature of duty in the Navy—namely, the military duties, irrespective of rating, and the particular duties of the rating in which men enlist or which they may attain; the importance of accurate knowledge; discipline; the rules of discipline; questions on discipline; the nature of an order; the nature of a command.

B. What the Navy offers.—The importance of being, first, a man-of-war's man, and, secondly, a specialist.—The various service schools; school for seaman gunners, artificers, etc., and the qualifications necessary in order to gain admittance to these schools.—The necessity of a good record in addition to special ability in any given line.—The ship itself as a training school, giving prominence to the fact that a man of the right type may gain advancement, whether a graduate of one of these schools or not, provided he is zealous and obedient.—Promotion in the Navy.—Difference between acting and permanent appointment.—The chances of obtaining warrant and commissioned rank.—Continuous service men.—Leave.—Liberty.—Shore duty.—Retirement.—Pensions.—Rewards and privileges.—Medals and gratuities.—Citizenship.

C. Enlistment in general.—Apprentice seamen.—Discharge.—The various types of discharges and the effects of punishment thereon.—The advantage of honorable discharge.—Transportation after discharge.—Service records.—Conduct classes.—Overstaying liberty and its ruin of all chances of advancement.—What constitutes desertion.—The fact that desertion will be punished, irrespective of the motive that prompted it.—The large percentage

of deserters recovered.—Punishment for deserters.—Types of naval courts-martial.

D. Pay table.—Accounts.—Extra allowances.—General remarks on pay.—Monthly money.—Loss of pay due to breaking liberty.—Example of a chief petty officer's pay.

E. Naval customs.—Rules concerning salutes.—Etiquette to officers and civilians.—General information about the Navy and its relation to the Government.—The President.—The Secretary of the Navy.—The commander in chief.—Captain.—Executive officer.—Officer of the deck.—Divisional officer.—The redress of wrongs.—Exercise of authority.—Quarrels and disturbances.

F. The general characteristics of the ships of the Navy.—Questions thereon.

G. General features of ships of the Navy of different classes.

H. The routine in port and at sea.—Bright work.—Sick call.—Quarters and drill.—Setting up.—Musters and inspections.—Messcs.—Watches and divisions.—Scrubbing and cleaning.—Duties of compartment cleaners.—Smoking hours.—Lucky bag.

I. The aim and object of all general drills; what it is intended to accomplish in a place other than that in which any particular man is stationed.—Fire.—Collision.—Abandon ship.—Fire and rescue.—General quarters.—Coaling ship.

J. Marking clothing.—Uniform, and regulations relating thereto.—Lashing hammocks.—Stowing bags.—Laying them out for inspection.—Airing bedding.—Stopping on wash clothes, bags, and hammocks.—Requisitions for clothing.—Care of clothing.

K. Personal cleanliness.—Elementary rules of hygienics.—Prophylaxis.—Elementary first aid.—Treatment of the wounded in action.—Typhoid prophylaxis.

L. Painting and the preparation of the surface therefor.

M. Swimming.—Restoring the apparently drowned.—Life buoys.—How the buoys should be dropped and when.

N. Athletics.—The attention given them on board ship.—The prestige attendant upon victory.—The various trophies awarded.

THE SUBJECTS THAT ALL CHIEF PETTY OFFICERS SHOULD KNOW.

31. All chief petty officers, irrespective of rating, must have a thorough knowledge of the following special subjects for all chief petty officers (this includes the special subjects for all petty officers): Responsibilities of chief petty officers.—Duties in general.—Privileges.—Pride in the performance of their duties.—Chances for advancement.—Duties at emergency drills (in general).—Uniform regulations.—Drill books.—Duties of beachmasters;

patrol officers.—Making guard trips.—Routine division duties.—In general, the duties of junior division officers.—The ideas and ideals of an officer.—The methods by which chief petty officers can obtain exact knowledge.

(Signed)

JOSEPHUS DANIELS.

NOTE.—Men of the engineer's force will find answers to many of the above requirements in this "Handy Book," in the preparations of which this General Order No. 63 has been followed. The general index of this book will be found to be an excellent guide for study to meet the requirements of the above order. A copy of General Order No. 63 should be obtained from the ship's writer and carefully studied.

PART I.

DUTIES OF THE VARIOUS RATINGS.

(A) RECIPROCATING ENGINES WITH COAL-BURNING BOILERS.

SECTION 1. THE COAL PASSER.

(a) This is the lowest rating in the engineer department. When a man enlists in the United States Navy, he wishes to become either a seaman or an engineer. If he has had no experience with machinery or the management of boilers, he is given the rating of coal passer. From the recruiting station he is sent to a receiving ship, where he is supplied with an outfit of clothing. He is also given one hammock, one set of hammock clews, and a bag in which to stow his clothes. He is allowed a ditty-box in which letter paper and toilet articles are generally kept. With these articles he is sent to a seagoing ship, where he is given a station billet. An illustration of a station billet is given below:

U. S. S. WEST VIRGINIA—STATION BILLET.

Ship's No., 6127. Name, Moore, J. W. Rating, C. P. No. 6127. Division, 6. Section, 1. Part, 1. Gun, _____. Boat, first sailing launch. Mess, No. 12. Battalion, _____. Company, _____. Clear ship for action, B-1. Fire station, No. 25, hose. Collision, No. 157. Arm and away, _____. Abandoning ship, first sailing launch. Hammock stows, No. 12, main deck port.

This station billet is made to read as follows: J. W. Moore, a coal passer, on board the U. S. S. *West Virginia*, whose ship's number—that is, the number on his bag and hammock—is 6127. The 6 means that he is in the sixth division; the 1 means that he is in the first section in that division; and the 27 is his number in the section. He abandons ship in the first sailing launch, stows his hammock in No. 12 netting on the port side of the main deck, and eats his meals at No. 12 mess table. He does not belong to any gun, is not in the battalion or the arm-and-away party. At clear ship for action he passes coal in the starboard fireroom. At fire quarters he leads out and mans fire hose No. 25, and at collision quarters he sees that water-tight door No. 157 is closed. On receiving his station billet the coal passer should at once acquaint himself with all his stations. It is advised that he get some old-timer on the ship to take him around, indicating his stations and where his hammock

stows. New men are generally allowed a day in which to get acquainted.

(b) *His duties.*—1. New men are distributed among old men, and each man is assigned a cleaning station, which it is his duty to keep clean. At "turn to" each coal passer should go immediately to his station and commence work. If this station is in the firerooms he will be told by the water tender in charge what to do. The water tender distributes them at his discretion in order to complete as soon as possible the work that is going on. A new man will benefit by observing the work of experienced men and by doing what he is told.

2. When on steaming watch it is the duty of the coal passer to get the coal out of the bunkers for the use of the firemen. If the bunker is full and the coal is coming out from under the bottom of the door, which is partly raised, the buckets are filled and dumped in a ridge in front of the furnace doors. As the bunker empties, two or three coal passers work together; one enters the bunkers and fills the buckets, the other two carry them out and dump them as before. It is the duty of the coal passer to keep an accurate count of the number of buckets of coal used and to report the number to the water tender of the watch.

3. When fires are cleaned the coal passer wets the refuse — ashes. (Cleaning fires is the removal of the slag and clinkers from the grate bars in the furnace.) The refuse is wet from a hose connection to the sea valve, and the pressure of the sea water is sufficient.

4. Once each watch, and always after cleaning fires at about six bells, the ashes are hoisted. The coal passers fill the buckets and hook them to the ash hoist, signaling to the man running the whip when a bucket is hooked on ready for hoisting. A careful count of the number of buckets sent up must be kept and reported to the water tender of the watch.

5. It becomes necessary, once each watch, to haul the ash pans. The coal passer will soon catch on to the time when this is necessary; and he has to keep them clean, and keep from 1 to $\frac{1}{2}$ inch of water in them, taking care when filling them not to wet any part of the boiler.

(c) In order to fit himself for promotion a coal passer should practice firing when opportunity affords. He should have a complete knowledge of the use and location of all the sea valves in the firerooms and of the valves and strainers of the drainage system. He should learn the names of the various parts of the machinery and of the boilers, and how to act in case of a casualty, such as the bursting of a gauge glass or a leaky manhole joint. By working

with experienced men and watching how they go about their work, new men will soon catch on how to do their work in the most expeditious way, which they will find to be the easiest for themselves.

Through the kindness of Lieut. D. E. Theleen, United States Navy, I am able to present the following:

INSTRUCTION FOR COAL PASSERS FOR FIREMEN, SECOND CLASS.

In order that coal passers may quickly familiarize themselves with their duties and qualify for promotion the following list is published as a guide for study. Water tenders will give all possible assistance to men desiring to qualify. Firemen, second class, must be up on all these subjects, but have a more complete knowledge.

1. *Location and use of.*—Grate bars, bridge wall, combustion chambers, manholes and plates, boiler gaskets, hydrokineter, surface blow, bottom blow, gauge glass and water column, try cocks, steam gauges, sentinel valve, main stop valve and where operated, auxiliary stop valve and feed pumps, feed-check valves, connection doors, ash-pan doors.

2. *Duties of coal passer in fireroom on watch.*—How to transport coal, how to keep a correct tally, importance of correct tally, bunker water-tight door system, bunker drains, use of air locks.

3. *Firing.*—Cooling a furnace, methods of firing, use of slice bar, use of crowfoot, use of hoe and ash-pan hoe, method of cleaning fires, method of cleaning tubes.

4. *Location and use of sea valves in the firerooms.*—Pump suction, pump discharge, blow from boilers, ash wetting-down valves, Kingston valves.

5. *Drainage system.*—Location and care of valves and strainers.

6. *Casualties, behavior in case of.*—Leaky manhole joint, collapsed furnace, bursting of gauge glass, collision.

7. *Steam gauge.*—General idea of construction; how to read accurately; working pressures by.

SEC. 2. THE SECOND-CLASS FIREMAN.

Coal passers who have a good record, and have shown their ability to perform the work of a second-class fireman, are promoted to that rating.

(a) *Cleaning stations.*—Second-class firemen are usually assigned to the boilers for their cleaning stations. They must be familiar with the methods of cleaning the boiler and all its parts. They are further required to scale and to turbine tubes, and to make minor repairs to the boiler and its fittings.

(b) *Duties when on steaming watch.*—His duty is to coal and clean the fires, under both natural and forced draft. He must know how to start and stop the auxiliary feed pumps in the firerooms in case the main feed pumps fail to feed. He must know how to act in the case of any casualty and how to read the pressure gauges. In regard to carrying fires, the light fire is the best to carry; and, in the long run, the tedious work of cleaning fires is much reduced.

(c) *Promotion.*—In order to qualify for promotion a fireman second class must have a thorough knowledge of the following:

1. How to fire and clean fires under any draft.
2. How to replace a broken grate bar.

3. The names of the different parts of a boiler.
4. The names and the use of the internal and external fittings of a boiler.
5. A general knowledge of the forced-draft system.
6. The use of the feed pumps.
7. A general knowledge of the auxiliary machinery in the fire-room and of the fireroom drainage system.
8. The names of and the system of issuing tools.

SEC. 3. THE FIRST-CLASS FIREMAN.

(a) A first-class fireman has more responsibility than a fireman second class. He must be a good fireman and have good executive ability in order to be able to relieve the water tender of the watch if ever his absence becomes necessary. He must be able to make slight repairs and know fully what to do in the case of the carrying away of any part of the boiler. He must know how to cut in and cut out boilers, and how to check combustion; as, for instance, if the time of getting underway is delayed an hour or so.

(b) A first-class fireman desiring promotion to water tender must know how to fire with the different kinds of coal, and he must be fully prepared in all the requirements of the above two sections. He must know how to start all pumps and how to prevent the entrance of salt water into the boilers. He must have a thorough knowledge of the gauge glass and try cocks, and the construction of all valves in the engineer department and their uses, and he must know how to seat a valve. He must know how bunkers are drained and how to estimate the amount of coal in the bunkers at any time. He must be familiar with the method of sweeping tubes, turbinizing tubes, how to clean the fire side of a boiler, how to renew grate bars and fire brick without having to haul fires; a complete knowledge of all steam traps, valves, piping, and machinery in the firerooms. He must know how to run the evaporators and distillers, and how to stand ice-machine watch. He must be fully familiar with the machinery of steam launches and motor boats.

SEC. 4. THE OILER.

(a) The oiler takes his name from the duties that he performs. When on steaming watch it is his duty to be continually examining the parts of the machinery under his care. He must see that the oiling wicks do not clog up with oil and that the flow of oil is sufficient but not too much. He shall frequently feel all the moving parts, slippers, guides, eccentrics, crossheads, crank pins, thrust bearings, and the stern tube bearing, to see that they are not running hot. He shall keep the handrails wiped off and the engine-

room floor plates swept up clean (under ordinary steaming this becomes necessary about three times a watch). He shall examine the water service frequently, and if it is used on the main thrust blocks bearings he shall see that no water works its way into the thrust proper. He must keep account of the oil he uses and report the amount to the chief machinist mate of the watch. On being relieved he shall report to the engineer officer of the watch when relieved, that he has been over all parts of the machinery with his relief. When going on watch an oiler must go over all parts of the machinery that he will be held responsible for, and, when satisfied that all is in good working order, he shall report to the engineer officer of the watch as relieving such and such a man, and that he has found everything in good shape.

(b) An oiler is required to have a practicable working knowledge of the main engines, all valves, piping, and all the moving parts. He must know all the names of cylinder and valve-chest mountings, and where the cylinder drains and cylinder reliefs lead. He must be familiar with the construction of all machinery and tanks in the engine room, and the use of all pumps on the ship, and how to pump out the bilges and double-bottom compartments. He must know how to pump water into the feed tanks both at sea and in port. He must understand the oil manifolds and the system of sight oiling. He must have a thorough knowledge of the reversing and jacking engines, and how to connect or disconnect the latter. He must know how to start and shut down the forced-draft blowers in the firerooms. He must understand the procedure of "warming up" and how to do so through the jackets. He must know how to take "leads" when adjusting bearings and the purpose for doing so; and while in port he should become a useful helper to the chief machinist's mate in overhauling and making repairs. In the case of a bearing running hot while underway he must know how and what to do. In addition to the above he must know how to stand auxiliary watches on the evaporators and distillers, the ice machine and in the steam launch. He must be competent for all the requirements of the lower ratings and able to take temporary charge of a steaming watch in the firerooms if the water tender were injured or absent.

SEC. 5. MACHINIST'S MATE, SECOND CLASS.

(a) This is a rating that may be reached in several different ways:

1. A man who has had training and experience with machinery and also shop experience may take an examination at the time of his enlistment, which, if he is successful in passing, secures for him this rating.

2. When a man has served one enlistment and desires to become a machinist's mate, if he is recommended by his commanding officer, he is sent to a school of instruction at Charleston, S. C., and upon completing this course is given the rating of machinist's mate first or second class, depending on the result of his examination.

(b) A machinist's mate second class is required to have a practicable working knowledge of the main engines, valves, and propellers. He must understand the use of all main and auxiliary machinery on board ship, and of all steam traps, separators, feed-water heaters, condensers, and any derangement liable to occur to them and the remedies for same; the machinery of steam launches and motor boats and all piping systems throughout the ship. He must have a complete knowledge of the main and auxiliary steam and feed lines, the main and auxiliary exhaust lines, and the drainage system. He must be able to make minor repairs, such as the grinding and seating of valves and know how to make leaky joints tight. He must understand the use of the reversing and jacking engines and how to connect and disconnect the latter. He is required to know how to test a condenser for salt-water leaks, and have a thorough knowledge of the use and construction of all manifolds and piping to double bottoms, and the location of all watertight doors, and know how they are opened or closed. He must be able to do bench, vice, and machine-shop work, and know how to read blue prints. He must be fairly familiar with all the requirements for the lower ratings as set done above.

(c) The station of a machinist's mate, second class, when on steaming watch, is in the engine room, where he must be ready at all times to be called on to make minor repairs. He is usually responsible for the engine-room auxiliaries, some of the main engine bearings, and the regulation of the feed water in the feed tanks. He should be qualified to test the feed water for salinity.

SEC. 6. MACHINIST'S MATE, FIRST CLASS.

(a) A machinist's mate, first class, must have a thorough knowledge of all that is contained in the previous five sections of this book, and he must be able to take charge of a steaming or auxiliary watch and understand how to keep the log. He must be competent to correct all casualties as, for instance—1. Suppose the engineer officer of the watch is in the firerooms and the main air pump should stop; he must know how to find the cause and know what to do at once (see p. 65). 2. He must be able to take charge of the boilers, as in the case of priming. 3. He must fully understand the running of the evaporators both when in single and when in double effect. 4. He is required to also have a thorough knowledge of all the heating and drainage systems of the ship and all their appendages.

(b) When in port he must be able to take complete charge of an auxiliary watch, understanding fully the use and construction of all auxiliary machinery. He must be able to take charge of the repairing that is going on and understand how to take "leads" when adjusting bearings and the purpose for which they are taken. He must know how to take care of the indicators and how to attach them to the cylinders and take cards. He must fully understand the cut-off scales and attachments to the main engine valves, and he must know how to set the main engine valves.

SEC. 7. THE WATER TENDER.

(a) When in port the general charge of the cleaning and repairs going on in the firerooms (boilers) assigned to him is his duty, and to see that the firemen and coal passers are properly distributed in his compartment, and that they understand the nature of their work and how to go about it in the most rapid and efficient manner. The cleaning of the steam and fire sides of the boiler is very important, and he shall see that it is properly done, cautioning the men not to cut the metal. When cleaning a boiler he shall report the condition of the zincs to the chief water tender or the man who is in charge of the firerooms. Zincs are no longer fitted in many boilers.

(b) When on steaming watch the water tender has general charge of the boilers assigned to him and the men working at them. He should continually watch the water level and endeavor to keep it at a constant height in the gauge glasses. He must guard against priming, and, if it ever occurs, he should at once start to check it. (See p. 70.) He shall keep an accurate count of the buckets of ashes and coal used during his watch and report them to the chief water tender of his watch, or the chief machinist's mate in the engine room, for entry in the log. When he receives orders to sweep the tubes of his boilers he shall superintend it himself, seeing that it is completely and properly done. He must be ready to act quickly in the case of any casualty. He must understand the method of testing boiler water and of analysis of the flue gases.

SEC. 8. THE CHIEF WATER TENDER.

The chief water tender is in general charge of the boilers assigned him and of the men working at them. He receives his orders from the engineer officer of the watch, and he must see that his men are distributed in such a manner as to do as soon as possible the work to be done. When underway he should spend his time equally in all steaming compartments and be present at the remedying of any casualty. He shall see that all orders are promptly and

correctly executed and that boilers are correctly cut in and cut out. At the end of his watch he shall report the number of buckets of coal and ashes that have been used to the engineer officer of the watch. He must see that the required steam pressure is maintained and that the men fire often and lightly and that the firing of the furnace beds is even, no holes being allowed to appear. In the case of a time firing device he shall see that the men fire when the number of their furnace comes up on the indicator. When under forced draft he shall see that the air pressure ordered to be maintained is not exceeded. He must be familiar with and able to use the various methods of testing the water in the boilers and the constituents of the flue gases. He must be fully aware of the importance of maintaining the boiler casing tight, allowing no air leaks. He shall endeavor to check fires when coming to anchor, preventing the waste of fresh water occasioned by the "popping" of the safety valves. He shall frequently examine the bottom blow valves to boilers and assure himself that they are absolutely tight. He shall see that the bilges in the firerooms and coal bunkers are kept as clean and dry as is possible, and he shall be positive that suction to the drainage system in his compartments are kept clear. He must be fully familiar with all the requirements of the preceding seven sections and should be fairly accomplished in machine-shop work. He shall see that the boiler log, if one is required by the chief engineer, is correctly and completely kept.

SEC. 9. THE CHIEF MACHINIST'S MATE.

In order to become a chief machinist's mate a machinist's mate, first class, besides having a full, complete knowledge of all that is contained in the previous sections, must have good ability, be a good executive, dependable for the execution of orders, and understand fully how to distribute his men so as to obtain the best results in the shortest possible time. He must have had experience in taking charge of steaming watches and auxiliary watches, and must have a full, complete understanding of how to correct whatever casualty may occur.

A man desiring to qualify for this rating should study carefully the Navy Regulations, paying particular attention to the sections dealing with the engineer department. He is also referred to pages 7 and 8 of the Bluejackets' Manual, and his attention is directed to more advanced books on engineering. He must be thoroughly familiar with all that is contained in this book, and he should so fit himself that in case of an emergency he could take charge of the entire engineer department for a short time. He must be able to take a set of indicator cards from the main or any

other engine and know how to compute the indicated horsepower developed. (See pp. 40-46.) He must be familiar with the regulations applying to the engineer department when in dry-dock, and know what to do prior to entering or leaving same. He must be familiar with all deck machinery, and he must be an expert in machine-shop work. He must know how to test flue gases. He must know fully the methods of testing the water in the boilers. He must understand all the entries that are to be made in the log.

SEC. 10. THE STOREROOM KEEPER.

The storeroom keeper has charge of the storerooms in which the engineer's stores are kept. He is required to keep a list of all the stores issued and to whom issued. He shall see that all the tools that are issued during a day are returned to him at the end of working hours in the same condition as when issued by him. If they are broken or damaged he shall make a note of the cause, by whom last used, and place aside for survey. If any tool is missing he shall endeavor to find it; if not able to do so he shall report it to the engineer's office, with the name of the man to whom last issued, entering it in his notebook as lost and the date on which found to be missing. When an order is brought to him for waste, etc., he shall issue it and then send the order to the engineer's yeoman. All orders received should be marked "completed" when completed and turned in to the engineer's office at the end of working hours. The storeroom keeper is responsible for the order and cleanliness of the storerooms in his charge, and he shall be required to keep all bunker lamps and lanterns filled, trimmed, and ready for lighting. All tools should be kept in a systematic order and the steam-engine indicators should not be allowed to lie around where they may become damaged. On some ships he is required to keep the oil-supply tanks replenished and he should keep an accurate account in a book for that purpose of all oil expended. At 8 p. m. he shall see that all stores under his care are properly secured, that all lights are out, and that storeroom doors are locked. He should lay out a supply of waste, etc., required for night watches. If he goes ashore he must leave his keys with the engineer's yeoman, or where designated by the chief engineer. *They shall never be taken off the ship.* When preparing for sea he shall secure any article that would be liable to cause trouble during rough weather. The assignment to duty as a storeroom keeper is an honor, as this duty is a very responsible one and requires a good man to fill it right. A storeroom keeper should always be on the job, willing, and good natured. *When-*

ever a casualty occurs he must be present, open his storerooms, and supply at once whatever may be needed for quick repair work. When the amount of any item is reduced one-half he shall report it to the engineer officer of the watch, in order that additional supplies may be noted as required in that item. His work will be made much easier by order, cleanliness, and a careful record of all that occurs relating to the storerooms.

B. RECIPROCATING ENGINES WITH OIL-BURNING BOILERS—TURBINES WITH COAL OR OIL-BURNING BOILERS.

SEC. 11. PREPARATIONS FOR GETTING UNDERWAY—STEAM TURBINES.

1. Start forced lubrication pumps.
2. Start main air and circulating pumps 2½ hours before time set for getting underway. (Carry 8–10 inches vacuum.)
3. In starting any pump first open the drains, then the suction and discharge of the pump, then the exhaust, and, last of all, crack the steam valve to warm up the pump. The steam valve may now be gradually opened, and when the pump is free from water and running well, close the drains. In starting the main circulating pump it must be first jacked over one turn and left in starting position. It may be necessary to put a vacuum on the auxiliary exhaust line before this pump can be started.
4. Open automatic stop valve main steam line and drain maneuvering valves two hours before time set for getting underway.
5. In opening this valve care must be taken to crack the valve in order to warm up the line. As the line becomes hot, the valve may be opened full, and when full opening is reached remove the pin and cap on end of valve stem.
6. Turn steam on gland line.
7. See counter gear oiled and everything clear for turning.
8. Start jacking rotors, with throttle by-passes open one-half turn.
9. In case the engines have been standing by with steam turned on it will usually not be necessary to jack the engines, as the steam from the glands will furnish sufficient heat to keep the engine warm.
10. Take out jacking gears.
11. Take counter reading before turning the engines.
12. Inspect oil and water systems.
13. Turn engines, ahead and astern, each side, with each throttle.
14. Report ready for getting underway after the engines have been tried.

15. Try steering engine 45 minutes before getting underway.
16. Drain whistle and siren 30 minutes before getting underway.
17. Test engine room and fireroom telegraphs.
18. Shift auxiliary exhaust to main condenser when it is started.
19. Have fire and bilge pump ready.
20. Turn steam on augmentors 10 minutes before getting underway.
21. After getting underway close turbine drains.
22. Shift to cruising combination as soon as both engines are signaled to go ahead at the same speed.
23. Take a set of dummy clearances.
24. Watch carefully all bearings for signs of heating.
25. It is important to note that a cruising combination should not be used until it is certain that the steam pressure is high enough to make the required number of revolutions with the combination it is intended to use.

SEC. 12. SECURING MAIN ENGINES AFTER COMING TO ANCHOR.

1. Give necessary orders to firerooms about disposition of fires.
2. Close main automatic stop valves.
3. Shut steam off glands.
4. Secure anchor and steering engines.
5. Secure forced lubrication pumps and oil cooling pumps about an hour after engines have stopped.
6. Start evaporators to use up all extra steam if they are not already running.
7. Shift auxiliary exhaust to auxiliary condenser when it will take care of it.
8. Put in jacking gear.
9. Read and record engine counters.
10. Open turbine drains; turbines being jacked to drain points.
11. After about two hours secure main circulating and air pumps. Air pumps are run this length of time in order to draw all vapor and water out of turbines and thus keep them dry.

SEC. 13. WORKING THE FIRES—TIME FIRING.

[Figures in ○ are painted in red.]

The two-number system will be used in explanation of time firing. Suppose it to be as follows:

- | | | |
|-----------|----------------------------|-------------------|
| ③-④-⑤-①-② | Upper numbers painted red. | } Forward boiler. |
| 1-2-3-4-5 | Lower numbers brass. | |
| ⑤-①-②-③-④ | Upper numbers painted red. | } After boiler. |
| 2-3-4-5-1 | Lower numbers brass. | |

The system of firing will be as follows:

Suppose the intervals to be three minutes, No. 1 rings up on the time-firing indicator then—

(a) Push back and level fires of No. 1 brass, lower number, and at the same time—

(b) Coal No. ① painted number.

In three minutes from the time No. 1 rang up the firing interval annunciator will ring up No. 2, which interval will give plenty of time to work the furnaces marked No. ①.

When No. 2 rings—

(a) Push back and level fires No. 2, brass numbered furnace.

(b) Coal fires No. ② painted number furnace.

This system will continue until all five furnaces of each boiler in numerical number have been coaled, thus insuring that each furnace fire will be coaled and pushed back at regular intervals, and will also give enough bright fire to maintain an even steam pressure and consume the smoke to the greatest possible extent.

At each firing three shovelfuls of coal will be used as a "charge"—*no more; no less.* The slicing of fires will be done at the direction of the water tenders when in their opinion it is deemed necessary. It must be remembered that too much slicing hinders the man in keeping the fires in proper condition and is bad for coal economy.

Each watch should burn down and clean when hot their own fires, and when cleaning fires the signals will of course be disregarded for that furnace.

When hoisting or ejecting ashes the signals must also be followed. A short delay in getting out ashes is not to be considered as important as the continuous handling of the fires.

When coaling, raking, or cleaning fires, firemen must work quickly and close the furnace doors promptly.

When cleaning fires in any boiler the draft should be partly checked by partly closing the damper and by putting on the ash-pan doors of furnaces when cleaned.

When it becomes necessary to check the fires it will be done by the use of the dampers and the ash-pan doors; never by opening or cracking furnace doors.

Water tenders should regulate the feed so as to keep the water at from 1 to 3 inches from the bottom of the glass, and they must become familiar with the valve opening that will determine and give this level. The feed must be continuous and very regular. The practice of opening the valve allowing the water to rise high in the glass and then closing the valve is *wrong and bad.*

SEC. 14. GENERAL DUTIES WHEN BURNING OIL FUEL.

One of the best indications of the proper degree of combustion of oil is, as in the case of coal, the smoke made. Experience has shown the following facts to be proved:

- (a) Insufficient air gives a thick *black* oily smoke.
- (b) Too much air gives a thick *white* oily smoke.
- (c) When the air is just right the smoke is just noticeable.

Experience has further shown that proper mixture of air and oil can not be obtained by using too large tips. It has been found that the 1-millimeter tips supplied by the Schutte Koerting Co. burners give about the best atomization, and if an increase in the amount of oil burned is desired the number of burners should be increased and not the size of the tips.

With the installation on the U. S. S. *Utah* the following method of burning oil has been found to be the most satisfactory:

Keep a bed of clinkers over the entire grate (boilers can be used for coal burning if desired) about 8 to 12 inches thick. At about the center of the grate keep a ridge of clinkers and ashes high enough for the flames from burners to strike.

Watch the grate carefully and keep all holes in the clinker bed filled up with ashes.

Keep all openings in the furnace closed; ash-pan doors, furnace doors, etc., except the opening immediately surrounding the burners. Watch the smoke from time to time. If thick and black, speed up the blowers; if white and thick, slow down the blowers until a sufficient amount of air is being supplied, and no more, and no smoke can be seen.

A further check on the proper degree of combustion may be obtained by watching the flame from the burners. If short and white the combustion is good; if long and yellowish, the combustion is poor. Petty officers in charge of the steaming fire-rooms must keep all these facts in mind and to endeavor to burn oil on their watch as economically as possible.

Water tenders and firemen in charge of firerooms must understand that their ability to reduce smoke will be taken into account when making up their quarterly marks and recommendations for promotions.

SEC. 15. PROMOTIONS.

The matter of promotion is entirely in the hands of the man himself. Promotion depends upon skill and ability, zeal and attention to duty, capability and capacity for work, good conduct and deportment. Men must show in their work that they are qualified for the rates that they desire promotion to; and for petty officers ratings must show that they have ability to handle men and know how to exercise authority. Men who commit grave offense against the regulations can not hope for promotion or any material consideration. Breaking liberty, drunkenness, or any general disregard of orders are serious offenses, and men who so

deliberately commit themselves can not expect promotion, except in rare cases of exceptional efficiency or a decided indication of reform. If a man holds a rate, and by his bad performance of work and behavior shows that he is unfitted for it, he may have the rate taken away by sentence of a court, or, in most cases, by the captain. Men are encouraged to make the most and best possible use of their time to improve themselves in knowledge and ability to fit themselves for promotion. Men have the privilege of being sent to various service schools from time to time. The detail of men to such schools will depend largely on their records and the interest they show in their work. Requests for transfer for good and sufficient reason will generally be approved for action by the department. Usually an exchange for a man of the same rate must be arranged for.

In addition to the requirements set down previously in this book, the repetition and addition of requirements as set down below may help as a further guide for men who desire promotion:

A. *For the rating of fireman, second class.*—Must be recommended by the chief water tender and officer of section or station. To be recommended he must show a general willingness to work and learn; be prompt to obey orders, reliable and trustworthy; be neat and clean and show himself fitted for and interested in the naval service. Must be able to fire a boiler, start pumps, ash-hoist engines, etc. Must know the principal parts of a boiler and show a fair knowledge of the piping and apparatus on the station to which he belongs and a general knowledge of the apparatus in the engineering department. Must be able to do the general cleaning work in the engineer department. Must have actually fired a boiler under way for at least a month. He should also have had at least six months' service on a cruising ship unless he has had previous engineering experience. Must have a clear record for at least six months.

B. *Fireman, first class.*—Must be recommended by the chief petty officer and officer of his section or station. Must be physically strong enough to satisfactorily fire boilers continuously, both coal and oil. Must be able to fire and start fires, clean fires, and secure a boiler, tend water, and replace grate bars. Must thoroughly know all parts of a boiler, operation of pumps, ash hoist, ejectors, blowers, etc. Must be familiar with piping, drainage, and pumping systems and the location of all valves. Must understand means and methods of cleaning boilers, inside and outside, and the care of compartments, bilges, coal bunkers, and double bottoms. Should have a general knowledge of all the different apparatus in the engine and boiler rooms, its purpose and where located. Knowl-

edge of auxiliaries, such as evaporators, ice machines, steamers, and steering engine, will count favorably. Must have had at least six months' service as fireman, second class, and should have had a year and a half sea experience. Must have a clear record for six months.

C. Oilers.—Must be recommended by the chief petty officer and officer of his section or station. Must understand the operation of pumps of all kinds and of all auxiliary engines. Must have a knowledge of oiling by hand, wick feed, and forced lubrication. Must understand the cleaning and care of compartments. Must have good mechanical ability, sufficient to act as machinist helper, and must be able to do such jobs as grinding in valves, packing joints, and dismantling machinery. Must understand the use of differential falls, jacks, etc., and the ordinary machinist tools. Must understand the operation of evaporators, ice machines, and the machinery of steamers and of all engine and fire room auxiliaries. Should, as a rule, have had at least three years' service. Must be thoroughly reliable and sober, and capable of handling men. Record must show reliability and thorough attention to duty. Must have had at least two months' actual practice at oiling. Watch standing in dynamo room and the operation of 50-foot steamers may be considered oiler's duties.

D. Water tenders.—Must be recommended by chief water tender and officer of section or station. Must be an expert fireman and know how to tend water. Must understand firing with coal and oil and know how to instruct other men. Must understand systems of firing, use of blowers, dampers, etc. Must thoroughly understand construction of boilers and boiler-room auxiliaries, and be able to take independent charge of the cleaning and overhauling of boilers; take charge of boiler-room compartments and how to avoid corrosion. He must be thoroughly conversant with all safety precautions required in the boiler room, and with the care and overhaul of all safety devices, and be able to take proper precautions in the case of accident to the boilers, piping, or other machinery. He must understand all piping systems, connections, and the operations of all auxiliaries in the fireroom and engineering department. Must thoroughly understand stowage of coal in bunkers and the care of coal bunkers and double bottoms. Must understand precautions in handling fuel oil and methods of stowage used. Must have good mechanical ability. Must be able to grind in valves, pack joints, overhaul boiler fittings. Must have good eyesight. Must have shown actual ability in handling men; have a record of reliability and sobriety, and be forceful, energetic, careful, and zealous in the performance of his work. Must have actu-

ally stood a water-tender's watch for three months satisfactorily. Should have at least three years' service, and, preferably, have been an oiler.

E. *Machinist's mate, first class.*—Must be recommended by chief petty officer and officer of his station. Must show good qualities of a petty officer; be reliable, trustworthy, sober, and zealous. Must be able to overhaul any part of the main or auxiliary machinery, and show excellent mechanical ability; be able to get main engines ready for getting underway and to secure same on coming to anchor; be able to stand throttle watch. Must show general knowledge of boilers, piping, and apparatus in firerooms. Must have at least one year of service on a cruising ship.

NOTE.—Read carefully the preface to this book, which is based on General Order No. 63, "Instruction on board ship"; also study pages 1 to 8.

PART II.

GENERAL INFORMATION.

SECTION 1. USEFUL PRINCIPLES OF MATHEMATICS.

In all mathematics the decimal point is the mark of division between the units and the parts of units. For instance, one and one-half boxes of bread would be written 1.5 boxes. In adding, subtracting, and multiplying always write the decimal points under each other.

(a) *Addition*.—This is the uniting or joining of numbers. For example: Add 25.76 and 2.345. Write the decimal points under each other and add—

$$\begin{array}{r} 25.76 \\ 2.345 \\ \hline 28.105 \text{ Answer.} \end{array}$$

(b) *Subtraction*.—This is the reducing of a number by an amount to be taken away from it; the numbers must be written as in (a). The following is an example: Subtract 1.396 from 1.805:

$$\begin{array}{r} 1.805 \\ 1.396 \\ \hline 0.409 \text{ Answer.} \end{array}$$

(c) *Division*.—This is for finding the number of times one number is contained in another. For example: There are 16 boilers installed in a ship and it is required to divide 96 coal passers and 80 firemen among them. Solution:

$$\begin{array}{r} 6 \qquad \qquad 5 \\ \hline 16)96 \qquad 16)80 \\ 96 \qquad \qquad 80 \\ \hline 0 \qquad \qquad 0 \end{array}$$

Answer: 6 coal passers and 5 firemen to each boiler. To denote division the following signs are used: $4 \div 2$; $2 \overline{)4}$; $2)4$; $\frac{4}{2} = 2$.

(d) *Multiplication*.—The sign used is \times . This is for finding the result of taking a number a certain number of times instead of

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adding that number the number of times it is to be taken. **Example:** Multiply 3.4 by 4; $3.4 \times 4 = 13.6$ Answer. **Problem:** Divide 100 by 0.25 and multiply the result by 0.2468. It may be written and solved as follows:

$$\frac{100}{0.25} \times 0.2468 = 98.7200 \text{ Answer.}$$

$$\begin{array}{r} \text{Solution: } 025.)10000.(400 \qquad 0.2468 \\ \underline{10000.} \qquad \qquad \qquad 400 \\ \hline \qquad \qquad \qquad \qquad \qquad 98.7200 \text{ Answer.} \end{array}$$

When a number is multiplied by itself it is said to have been squared. When one number has been multiplied by itself two times it is said to have been cubed. To raise a number to the fourth power it must be multiplied by itself three times, and so on. A table of the squares and cubes of numbers will be found in Part 14. $(2)^4 = 2 \times 2 \times 2 \times 2 = 16$.

There is a simple rule for squaring numbers ending in 5.

Rule.—1. Drop the 5 of both numbers and multiply the remaining number by a number 1 greater than itself.

2. Suffix 25 to this result.

Example: Square 435—i. e., multiply 435 by 435.

1. Drop the 5 of both numbers. This leaves 43 by 43.

2. Multiply 43 by a number 1 greater, which is 44.

3. Then suffix 25.

Solution:

$$\begin{array}{r} 43 \\ 44 \\ \hline 172 \\ 172 \\ \hline 1892 \end{array}$$

To this result, 1892, suffix 25, and the square of 435 is 189225.
Proof:

$$\begin{array}{r} 435 \\ 435 \\ \hline 2175 \\ 1305 \\ 1740 \\ \hline 189225 \text{ Answer.} \end{array}$$

(e) *Fractions*.—In a fraction the number above the line is the numerator and the number below the line is the denominator. For instance, in the fraction $\frac{3}{4}$, 3 is the numerator and 4 is the denominator. This is a *proper* fraction. If the numerator is greater than the denominator, the fraction is said to be *improper*. A mixed number is a whole number and a fraction, as 2 and $\frac{1}{2}$ in $2\frac{1}{2}$.

1. *Addition of fractions*.—To add two fractions—that is, to combine them—add their numerators, if their denominators are the same, and reduce to lowest terms.

Example: Add $\frac{1}{3}$, $\frac{2}{3}$, and $\frac{4}{3}$

$$\begin{array}{r} 1 \\ 3 \\ 5 \\ - \\ 9 \text{ or } \frac{8}{3} = 1\frac{2}{3} \text{ Answer.} \end{array}$$

If the denominators are not the same, they must be made the same by finding the least number, called the *least common multiple*, that each denominator will divide into an even number of times, and then adding the *new* numerators and reducing to lowest terms. Problem: Add $\frac{1}{2}$, $\frac{2}{3}$, $\frac{7}{10}$, and $\frac{4}{5}$.

First find the least common multiple of the denominators:

$$\begin{array}{r} \text{L. c. m.: } 2) 2 \quad 18 \quad 20 \quad 6 \\ \hline 3) 1 \quad 9 \quad 10 \quad 3 \\ \hline 3 \quad 10 \quad 1 \end{array}$$

And the l. c. m.: $2 \times 3 \times 3 \times 10 = 180$.

Now multiply the numerators by the number of times their denominators are contained in the least common multiple and reduce to lowest terms, as follows:

$$\frac{1 \times 90}{2 \times 90} + \frac{3 \times 10}{18 \times 10} + \frac{7 \times 9}{20 \times 9} + \frac{5 \times 30}{6 \times 30} = \frac{90}{180} + \frac{30}{180} + \frac{63}{180} + \frac{150}{180} = \frac{333}{180}$$

and reducing to lowest terms, $\frac{333}{180} = 1\frac{153}{180} = 1\frac{17}{20}$ Answer.

2. *Subtraction of fractions*.—The same rule as used in adding must be used.

1. Find the least common multiple.

2. Find the new numerators and subtract them, then reduce to lowest terms.

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Example: Take $\frac{1}{2}$ from $\frac{7}{8}$. The least common multiple is 8; the new numerators are 3×2 and 7×1 ; then 6 from 7 leaves 1, and the answer is $\frac{1}{8}$.

3. *Multiplication of fractions.*—Multiply the numerators and denominators and reduce to lowest terms. Example:

$$\frac{1}{2} \times \frac{7}{8} = \frac{7 \times 3}{3 \times 12} = \frac{7}{12} \quad \text{Answer.}$$

To multiply a fraction by a whole number, multiply the numerator or divide the denominator. Example:

$$\frac{1}{2} \times 4 = \frac{3 \times 4}{4} \quad \text{or} \quad \frac{1}{2} = \frac{12}{4} \quad \text{or} \quad \frac{3}{1} = 3 \quad \text{Answer.}$$

4. *Division of fractions.*—To divide a fraction by a whole number multiply the denominator or divide the numerator. To divide one fraction by another fraction, invert the other and multiply.

Example: Divide $\frac{3}{4}$ by $\frac{8}{9}$.

$$\frac{3}{4} \div \frac{8}{9} = \frac{3}{4} \times \frac{9}{8} = \frac{27}{32} \quad \text{Answer.}$$

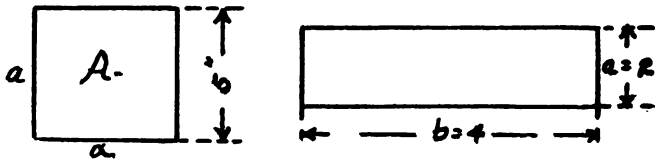
5. *A complex fraction* is one in which either the numerator or denominator (or both) consists of a fraction or mixed number.

Example: Solve the complex fraction—

$$\frac{2\frac{1}{2}}{8.5} = \frac{5}{2} \div \frac{17}{2} = \frac{5}{2} \times \frac{2}{17} = \frac{5}{17} \quad \text{Answer.}$$

SEC. 2. HOW TO FIND AREAS AND VOLUMES.

(a) *To find the area of a square.*—Multiply the length of one side by itself. As in the figure $A = a \times a$. Let A = area, and $a = 5$ = the



length of one side; the $A = 5 \times 5 = 25$. Answer. $a = 5''$ $A = 25$ square inches.

(b) *To find the area of a rectangle.*—Multiply one side by the adjacent side. In the figure a is one side and b is the adjacent side. Then $A=a \times b=2 \times 4=8$ square inches. Answer.

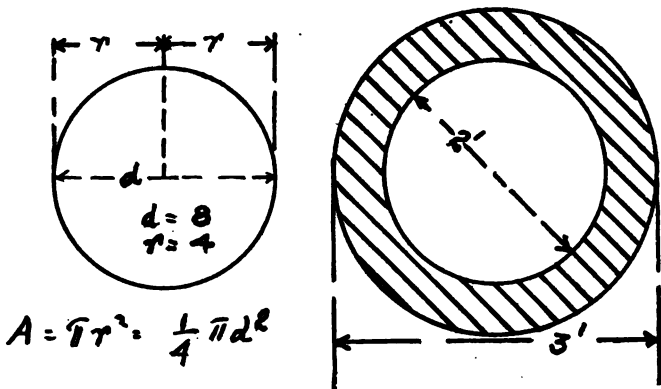
(c) *To find the area of a circle.*—Square the radius and multiply the result by a constant called “pi” (π). This constant equals 3.1416. As in the figure, r =radius=4; then $A=4 \times 4 \times 3.1416=50.2656$. Tables of the areas of circles may be found in various handbooks. They should be used. A small table is appended to this book in Part 13. Since the radius is equal to one-half the diameter the area will be equal to the following:

$$A=r \times r \times \pi=4 \times 4 \times 3.1416=50.2656 \text{ square inches.}$$

or

$$A=\frac{d}{2} \times \frac{d}{2} \times \pi=\frac{8}{2} \times \frac{8}{2} \times 3.1416=50.2656 \text{ square inches.}$$

(d) *To find the sectional area of a ring or pipe.*—1. Find as in (c) above the area of the inner and outer circles. 2. Take the differ-



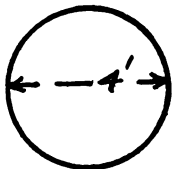
ence between the two areas. Let the pipe be $\frac{1}{4}$ " thick and the inner diameter 2 inches (2"). Find the area of a section of the metal.

$$A \text{ (small circle)}=3.1416 \times \frac{2}{2} \times \frac{2}{2}=3.1416$$

$$A \text{ (large circle)}=3.1416 \times \frac{3}{2} \times \frac{3}{2}=7.0686$$

$$A \text{ (of section)}=7.0686-3.1416=3.927 \text{ square inches.}$$

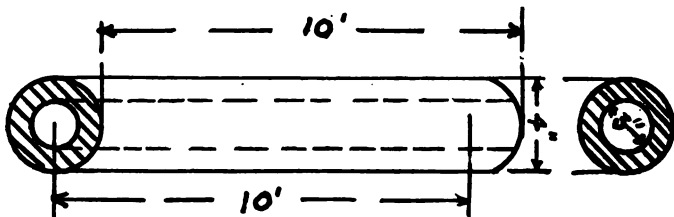
(e) *To find the length of circumference of a circle.*—Multiply the diameter or twice the radius by 3.1416 (π). As in the figure, let $d=4$ feet. Then the circumference (c)= $4 \times 3.1416=12.5664$ feet. Answer: $C=2\pi r=\pi d$.



(f) *To find the areas of the inner and outer surfaces of a pipe or tube.*—First find the lengths of the inner and outer circumferences as in (e). Multiply the results by the length of the pipe or tube.

Example: Given a boiler tube with dimensions as shown, find the areas of its inner and outer surfaces. (Note: This has to be done when computing the heating surface—H. S.—of a boiler.) Solution

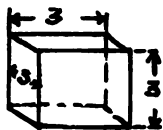
1. Circumference of inner surface: $=3.1416 \times 3=9.4248$ inches.
2. Circumference of outer surface: $=3.1416 \times 4=12.5664$ inches.



3. Area of inner surface (10 feet $=10 \times 12$ inches): $=9.4248 \times 10 \times 12=1131.976$ square inches. Answer.

4. Area of outer surface: $=12.5664 \times 120=1507.968$ square inches. Answer.

(g) *To find the area of the surface of a sphere.*—Square the radius and multiply the result by $4 \times \pi$. As shown in the figure, the sphere is of 4 feet diameter and it is desired to find the area of its surface.



Surface area $=3.1416 \times 2 \times 2 \times 4=50.2656$ square feet. Answer.

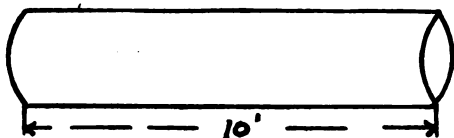
(h) *To find the volume of a cube.*—Multiply the length of one side twice by itself. Given a cubical box of dimensions as shown in the figure, to find its contents, or volume:

Let V = volume.

Then $V=3 \times 3 \times 3=27$ cubic inches. Answer.

(i) *To find the volume of a cylinder.*—Find the area of one end and multiply this area by the length, height, or altitude. Given a cylinder of dimensions as shown in the figure, to find its volume:

$$\text{Area of one end of the cylinder} = \frac{3.1416 \times 2 \times 2}{4} = 3.1416 \text{ square feet.}$$



The $V = 3.1416 \times 10 = 31.416$ cubic feet.

(j) *To find the volume of the sphere of (g).*—Cube the radius and multiply the result by $4/3$ of (3.1416). The volume of the above sphere $= 4/3 \pi r^3$.

$$4/3 \times 3.1416 \times 2 \times 2 \times 2 = 33.5104 \text{ cubic inches. Answer.}$$

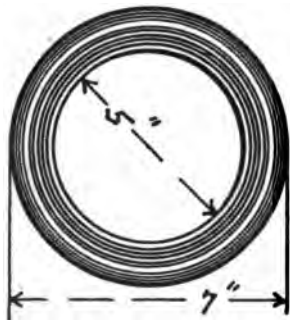
(k) *To find the solidity of a cylindrical ring.*—To the thickness of the ring add the inner diameter; this sum multiplied by the square of the thickness and again by 2.4674 will give the solidity.

Example: Given to make a deck stopper with a ring of the dimensions as shown in the figure. To find the solidity—that is, the amount of metal required to make the ring:

$$1. D \text{ plus } t = 5 + 1 = 6 \text{ inches.}$$

$$2. t \text{ squared} = 1 \times 1 = 1 \text{ square inch.}$$

$$3. \text{Solidity} = 6 \times 1 \times 2.4674 = 14.8044 \text{ cubic inches. Answer.}$$



SEC. 3. MEASUREMENTS OF TANKS.

To find the cubical contents of a tank or the number of gallons of water contained in any tank, first

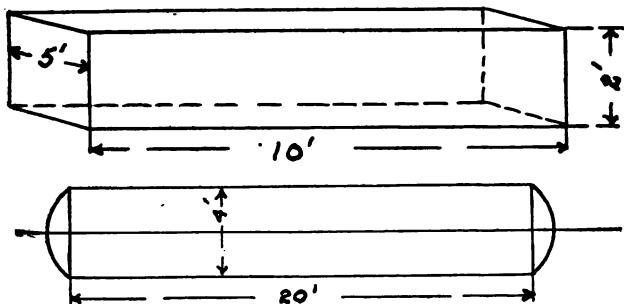
find the volume of the tank in cubic feet and then multiply this result by 7.4805, reducing the cubical contents to gallons.

1. To find the number of gallons of water contained in a rectangular tank of dimensions as shown in the figure:

$$(a) \text{ Cubic contents} = 10 \times 5 \times 2 = 100 \text{ cubic feet.}$$

$$(b) \text{ Water contained} = 100 \times 7.4805 = 748.05 \text{ gallons. Answer.}$$

2. To find the number of gallons contained in a cylindrical tank, such as the water drum of a boiler.



Given a water drum of dimensions as shown in the figure, to find the number of gallons of water it will hold when it is one-half full:

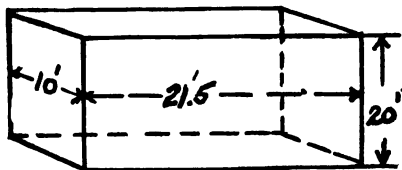
$$(1) \text{ A of end} = \frac{3.1416 \times 4 \times 4}{4} = 12.5664 \text{ square feet.}$$

$$(2) \text{ V when one-half full} = \frac{1}{2} \times 20 \times 12.5664.$$

$$(3) \text{ Number of gallons} = \frac{1}{2} \times 20 \times 12.5664 \times 7.4805 = 940.0235 \text{ gallons. Answer.}$$

SEC. 4. CAPACITY OF BUNKERS.

1. To find the capacity of a rectangular bunker.—First find the cubical contents in cubic feet and then reduce this result to tons by dividing by the number of cubic feet per ton, generally taken as 43 cubic feet=1 ton.



Example: A bunker is of dimensions as shown in the figure; to find the number of tons of coal it will hold when full:

$$(1) \text{ Cubic contents} = 20 \times 10 \times 21.5 = 4,300 \text{ cubic feet.}$$

$$(2) \text{ Number of tons of coal} = \frac{4,300}{43} = 100 \text{ tons. Answer.}$$

2. To find the capacity of a bunker whose forward end is of greater area than its after end, as shown in the figure giving dimensions, first find the mean depth and mean width as follows:

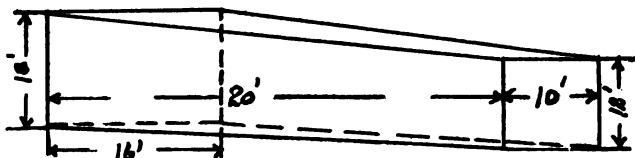
(1) Mean width = $\frac{10+16}{2} = 13$ feet.

(2) Mean depth = $\frac{18+12}{2} = 15$ feet.

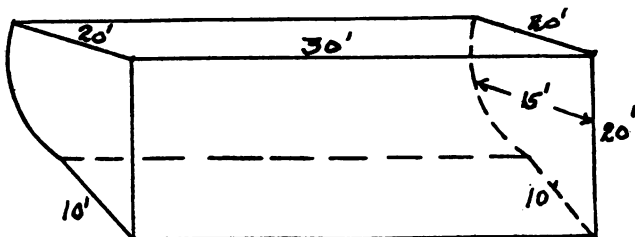
(3) Cubic contents = $13 \times 15 \times 20$.

(4) Number of tons of coal it will hold when full: $\frac{13 \times 15 \times 20}{43} =$

90.7 tons. Answer.



3. To find the capacity of a bunker whose outboard side is formed by the rounded side of the ship, first find the area of one end and multiply this area by the length.



Example: Given a bunker of dimensions as shown in the figure below, find its capacity:

(1) Add the top and bottom sides of one end and divide by 2, as $10+20=30$, and $30+2=15$.

(2) Then multiply this result by 4 and add the top and bottom sides of the same end to this result; then divide by 6, as

$$\frac{(15 \times 4) + 10 + 20}{6} = 15.$$

Multiply this mean ordinate by the depth, giving area of one end. The area of this end multiplied by the length will give the cubical contents, and dividing this result by the number of cubic feet per ton will give the capacity.

$$\text{Whence: Capacity} = \frac{15 \times 20 \times 30}{43} = 209.3 \text{ tons of coal. Answer.}$$

SECTION 5. HOW TO FIND THE INDICATED HORSEPOWER OF AN ENGINE AND COMPUTE INDICATOR CARDS.

All men above the rating of machinist's mate, second class, should be able to find the indicated horsepower developed by an engine, and understand fully the taking of indicator cards and how to work out results from them.

Indicated horsepower.—This is the term used to express the power developed by an engine.

When a weight of 1 pound has been raised a distance of 1 foot in 1 minute we say that the work (power) necessary to do this is equal to 1 foot-pound (ft. lb.) per minute. One indicated horsepower (I. H. P.) is equal to 33,000 times 1 foot-pound per minute, and is expressed:

1 I. H. P. is equivalent to 33,000 foot-pounds per minute,
 or 1 I. H. P. is equivalent to $550 = \frac{33,000}{60}$ foot-pounds per second,
 or 1 I. H. P. is equivalent to $33,000 \times 24 = 792,000$ foot-pounds per hour.

Therefore, if we have an engine that is producing 33,000 foot-pounds of work every minute, we say that this engine is developing 1 indicated horsepower (1 I. H. P.). If it is producing 33,000,000 foot-pounds per minute, we say that it is developing 1,000 indicated horsepower.

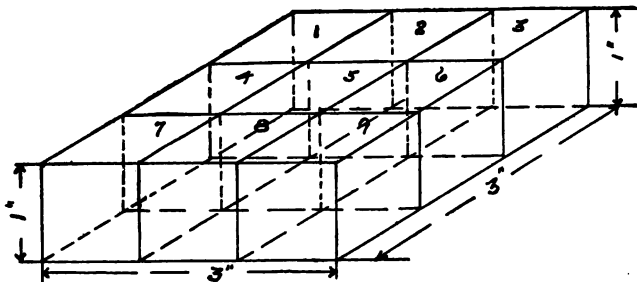
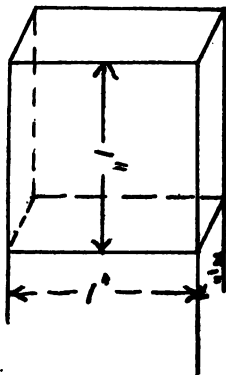
Now, the question is, How do we make an engine do this work and find how much it is doing? In section 2, part 9, the "water-steam circuit," we have shown that the steam in the cylinders of an engine is made to do work by pushing against a piston contained in the cylinder, making the piston move up and down. In section 1, part 9, page 110, "main engine complete," we have found that this up-and-down movement of the piston is transmitted (passed on) by means of a piston rod, crosshead, crosshead slide, connecting rod, and shafting into a rotary motion, causing the propeller to revolve, making one complete revolution each time the piston passes from one end of the cylinder to the other and back again—i. e., the piston makes two strokes. Therefore 1 revolution of the propeller will be made in 2 strokes of the piston (1 up

stroke and 1 down stroke=2 strokes=1 revolution=1 revolution per minute if each stroke is made in 30 seconds).

If we have an engine that is developing 100 indicated horsepower at 100 revolutions, it is customary to say 100 I. H. P. at 100 r. p. m.; or, say, 300 I. H. P. at 300 r. p. m.; or, say, 500 I. H. P. at 500 r. p. m. This shows that the power developed by an engine increases or decreases exactly as the revolutions, other factors being the same.

It is now necessary to bring in the work item. It has been shown under section 2, part 6, page 93, "steam-pressure gauges," that steam exerts a pressure in pounds per square inch (lbs. per sq. in.).

If we have a block of 1 cubic inch of lead, as shown in the sketch, where each side is exactly 1 inch in length, then the surface on which this block rests is exactly $1 \times 1 = 1$ square inch; and supposing that the cubic inch of lead weighs exactly 1 pound, we then have a pressure of 1 pound per square inch. If the block of lead weighed 2 pounds, we would have a pressure of 2 pounds per square inch. Now, suppose that the top of the table has an area of 9 square inches, and that it is loaded with blocks of lead, each block containing 1 cubic inch of lead weighing 1 pound, and that there are 9 of these blocks (see sketch below):

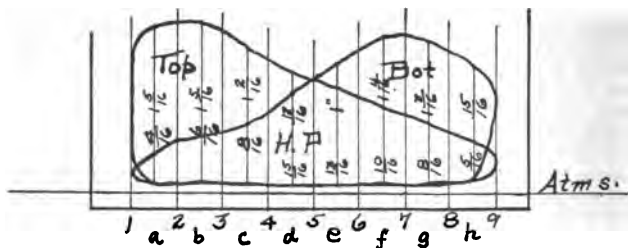


Here we have a table of surface area of $3 \times 3 = 9$ square inches, and resting on it there are 9 1-pound blocks of lead, and as each block covers a surface of 1 square inch, the 9 blocks cover the entire

top of the table of 9 square inches. Then the total pressure on the top of the table is $9 \times 1 = 9$ pounds. If we want the unit pressure we divide by the surface area and find that the unit pressure is

$$\frac{9}{9} = 1 \text{ pound per square inch.}$$

In an engine cylinder there exists a certain average pressure throughout a stroke which is called the "mean effective pressure (m. e. p.)," and is represented by the small letter "p," always expressed in pounds per square inch. This m. e. p. acts on the total surface of the piston, which we know has an area of, say, "a" square inches. Then the total pressure exerted on the piston will be $= p \times a$ pounds. In order to find the value of "p" (m. e. p.) an instrument called the "steam-engine indicator" is used, and from the indicator cards we obtain the m. e. p. The distance that the piston moves in going from one end of the cylinder to the other is called the stroke,



and is equal to, say, "1" feet. Therefore, combining these units, an expression is obtained for the power developed in one end of the cylinder of an engine, and this expression is:

$$\text{I. h. p.} = \frac{p \times l \times a \times n}{33,000}$$

In which—

p—mean effective pressure in pounds per square inch.

l—length of stroke in feet.

a—area of piston in square inches.

n—number of revolutions per minute.

As power is developed in each end of the cylinder, the total indicated horsepower developed in the cylinder $= \frac{2p \times l \times a \times n}{33000}$.

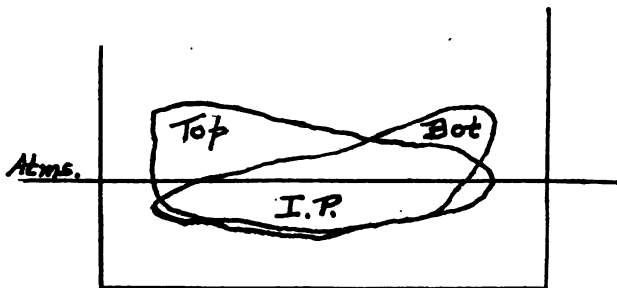
The above formula may be used for the rapid calculation of power, but it is not rigidly correct, as the bottom or "crank end" of the cylinder contains the piston rod, and hence the effective area of that side of the piston is less by the area of the rod. If D is the diameter of the piston its area is $\frac{1}{4}\pi D^2$ square inch, and if d is the diameter of the piston rod the net (effective) area of the bottom side will be $\frac{1}{4}\pi D^2 - \frac{1}{4}\pi d^2 = \frac{\pi(D^2 - d^2)}{4}$ square inches; and from these values we obtain the exact formula.

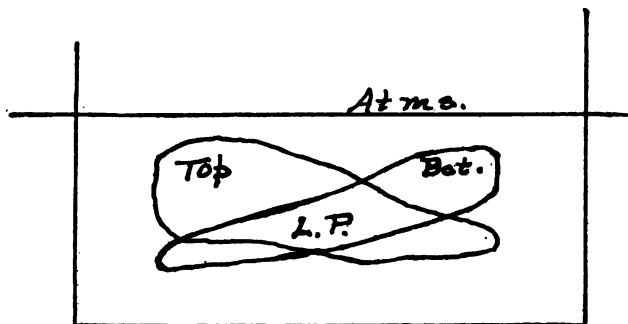
The total indicated horsepower developed in the cylinder of an engine:

$$\begin{aligned} &= \frac{p \times l \times n \times \pi \times D^2}{33000 \times 4} + \frac{p \times l \times n \times \pi (D^2 - d^2)}{33000 \times 4} \\ &= \frac{p l n \pi}{33000} \left\{ \frac{D^2}{4} + \frac{D^2}{4} - \frac{d^2}{4} \right\} \\ &= \frac{p l n \pi}{33000} \left\{ \frac{D^2}{2} - \frac{d^2}{4} \right\} \end{aligned}$$

Example.—To illustrate the application of the above formulas let it be required to find the indicated horsepower developed by a triple expansion four-cylinder engine of the following dimensions, at 150 revolutions per minute: $18'' \times 30'' \times (2)42'' \times 36''$, piston rods $9''$.

The set of cards following were taken from this engine.





To be divided and measured as for the horsepower.

Solution: The indicator cards are either measured by an instrument called the "Planimeter" (or averaging instrument) or they are measured as follows: Divide the base of each card into any equal number of parts, 1, 2, 3, 4, 5, 6, 7, 8, and redivide as at a, b, c, d, e, f, g, h. See page 42. These ordinates measured as follows:

H. P.		I. P.		Both L. P.	
Top.	Bot.	Top.	Bot.	Top.	Bot.
$1\frac{5}{16}$	$\frac{4}{16}$	1	$\frac{8}{16}$	$\frac{7}{16}$	$\frac{4}{16}$
$1\frac{5}{16}$	$\frac{6}{16}$	$1\frac{3}{16}$	$\frac{6}{16}$	$\frac{5}{16}$	$\frac{5}{16}$
$1\frac{2}{16}$	$\frac{8}{16}$	$1\frac{3}{16}$	$\frac{8}{16}$	$\frac{8}{16}$	$\frac{8}{16}$
$\frac{13}{16}$	$\frac{12}{16}$	$1\frac{1}{16}$	$\frac{10}{16}$	$\frac{7}{16}$	$\frac{6}{16}$
$\frac{13}{16}$	1	$\frac{14}{16}$	$\frac{10}{16}$	$\frac{7}{16}$	$\frac{7}{16}$
$\frac{10}{16}$	$1\frac{4}{16}$	$\frac{11}{16}$	$\frac{10}{16}$	$\frac{6}{16}$	$\frac{8}{16}$
$\frac{8}{16}$	$1\frac{1}{16}$	$\frac{8}{16}$	$\frac{12}{16}$	$\frac{12}{16}$	$\frac{10}{16}$
$\frac{6}{16}$	$\frac{15}{16}$	$\frac{4}{16}$	$\frac{7}{16}$	$\frac{3}{16}$	$\frac{3}{16}$
$\frac{6}{16}$	$\frac{15}{16}$	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{16}$
$6\frac{1}{16}$	$6\frac{4}{16}$	$6\frac{1}{16}$	$4\frac{9}{16}$	$3\frac{1}{16}$	$3\frac{2}{16}$
8)6.938	8)6.250	8)6.750	8)4.563	8)3.250	8)3.125 in.
.867	.781	.844	.571	.406	.391 av.

We will suppose that these cards were taken with indicator springs corresponding to pressures as follows:

For the H. P. 1" of height=100 pounds per square inch.

For the I. P. 1" of height= 50 pounds per square inch.

For the L. P. 1" of height= 20 pounds per square inch.

Then the m. e. p. for the cylinders will be:

H. P. top	m. e. p. = $100 \times .867 = 86.7$	pounds per square inch.
H. P. bottom	m. e. p. = $100 \times .781 = 78.1$	pounds per square inch.
I. P. top	m. e. p. = $50 \times .844 = 42.2$	pounds per square inch.
I. P. bottom	m. e. p. = $50 \times .571 = 28.55$	pounds per square inch.
F. L. P. top	m. e. p. = $20 \times .406 = 8.12$	pounds per square inch.
F. L. P. bottom	m. e. p. = $20 \times .391 = 7.82$	pounds per square inch.

The after L. P. happens to be the same as the forward L. P. (F. L. P.).

It is now necessary to find the areas on which these m. e. p.'s act, and as the diameters are given, we find from the table of areas that they are as follows:

Area of piston rod—63.62 square inches.

Area of H. P. piston—254.47 square inches top and 190.85 bottom.

Area of I. P. piston—706.86 square inches top and 643.24 bottom.

Area of L. P. piston—1,385.4 square inches top and 1,321.78 bottom.

[Note: Bottom=top—63.62.]

Substituting in the formula $I. H. P. = \frac{\text{plan}}{33000}$ we obtain—

$$I. H. P. \text{ H. P. top} = \frac{86.7 \times \frac{36}{12} \times 254.47 \times 150}{33000} = 300.8$$

$$\text{Bottom} = \frac{78.1 \times 3 \times 190.85 \times 150}{33000} = 203.3$$

$$\text{Total i. h. p. h. p. cylinder} = 504.1$$

The other cylinders should be solved by the student. The results will be found to be:

$$\text{Total I. H. P. in I. P. cylinder} = 657.2$$

$$\text{Total I. H. P. in F. L. P. cylinder} = 294.2$$

$$\text{Total I. H. P. in A. L. P. cylinder} = 294.2$$

Therefore the total I. H. P. developed by the engine will be equal to the sum of that in each cylinder or—

$$504.1 + 657.2 + 294.2 + 294.2 = 1749.7 \text{ I. H. P. Answer.}$$

[NOTE.—This is a sample of unequal—that is, poor cylinder division—of work.]

Observation of the formulas deduced above show that there is one term that is constant throughout and that is $\frac{1 \times r. p. m.}{33000}$.

In actual practice to simplify these solutions on board ship a table should be made giving the following data:

1. Area of H. P. piston.
2. Area of I. P. piston.
3. Area of L. P. piston (forward and after).
4. Area of all piston rods.
5. A table giving the values of the following:
 1. For H. P. cylinder $\frac{la \times r. p. m.}{33000}$ top and bottom.
 2. For I. P. cylinder $\frac{la \times r. p. m.}{33000}$ top and bottom.
 3. For each L. P. cylinder $\frac{la \times r. p. m.}{33000}$ top and bottom.

SEC. 6. PAY TABLES.

1. First enlistment.

Rate.	Base pay.	Monthly pay.
Chief machinist's mates.....	\$70.00	\$77.00
Boiler makers.....	65.00	71.50
Machinist's mates, first class.....	55.00	60.50
Coppersmiths.....	55.00	60.50
Chief water tenders.....	50.00	55.00
Blacksmiths.....	50.00	55.00
Water tenders.....	40.00	44.00
Machinist's mates, second class.....	40.00	44.00
Oilers.....	37.00	40.70
Firemen, first class.....	35.00	38.50
Firemen, second class.....	30.00	33.00
Coal passers.....	22.00	24.20

2. Whenever a man reenlists within four months after the expiration of his first enlistment, he is credited with four months' pay. He also receives for reenlisting an increase of \$6.36 on his base pay per month. For example, a fireman, second class, reenlists at the expiration of his first enlistment one month after it had expired. He is given four months pay, amounting to \$132, and his base pay of \$30 is increased to \$36.36, making his monthly pay \$40.

3. Each month 20 cents is deducted out of the monthly pay as a hospital fee.

4. Chief water tenders, after serving one year as such, if they qualify by examination for permanent appointment, have their pay, from the date of the examination, increased to \$77.

5. On the second reenlistment the base pay of Table 1 is increased \$6.36 plus \$4.36, and if the man has a good-conduct medal it is further increased \$0.75, making the base pay of a chief machinist's mate, for example, on second reenlistment, \$81.47 and his monthly pay \$89.62.

6. Service pay of a chief machinist's mate:

First enlistment.....	\$77.00	Fourth reenlistment....	\$100.86
First reenlistment.....	84.00	Fifth reenlistment.....	106.48
Second reenlistment....	89.62	Sixth reenlistment.....	112.10
Third reenlistment.....	95.24	Seventh reenlistment..	117.72

SEC. 7. GLOSSARY OF TERMS AND DEFINITIONS.

1. **Air-pressure gauges (manometer).**—For measuring the pressure of the air or "draft" when using forced draft.

2. **Air locks.**—For communication between the firerooms, or between the compartments under air pressure and those not under pressure.

3. **Air cock.**—Each boiler is fitted with an air cock on the shell or steam drum, to permit the escape of air when filling the boiler with water and to show when the boiler is full. Should always be opened when filling a boiler.

4. **Bedplates.**—They are made of cast iron and are used to support the engine.

5. **Boiler covering.**—The shell of a boiler is covered with an incombustible, nonconducting material, known as magnesia, to prevent the radiation of heat. This is usually covered (laggered) with thin galvanized sheet iron to protect the shell and covering from moisture.

6. **Bottom blow valve.**—These are generally seatless composition valves fitted to each boiler by means of which the boiler may be blown down.

7. **Banked fires.**—Heavy banked fires are not allowed except in cases of emergency, and when fires are banked, the ash-pan doors are to be kept open. In a banked fire the fire is generally shoved to the back of the grate and covered with green coal; the draft is deadened, and the fire burns slowly.

8. **Bridge wall.**—In Babcock & Wilcox boilers is brick back wall of the furnace. In shell boilers this limits the extent of the fires, and by reducing the opening at the back of the furnace increases the speed of the gases of combustion and thus produces a more complete mixture in the combustion chamber.

9. **Cylinders.**—They are made of cast iron. The heat energy of the steam admitted into the cylinders is converted into work, the pressure of the steam forcing the pistons and rods up and down.

Cylinders often contained liners of high-grade close-grained cast iron.

10. **Crossheads.**—They are made of steel, and are used to connect the piston rods and connecting rods.

11. **Crosshead guides.**—They are made of cast iron. The cross-head slippers working in these guides control the motion of the crossheads in a straight line up and down.

12. **Crosshead brasses.**—They are made of composition and are lined with white metal. Used to connect crossheads and connecting rods.

13. **Connecting rods.**—Made of high-grade steel machinery forgings and transmit the motion of the piston rods to the crank shafts, converting it from reciprocating into a rotary motion.

14. **Crank-pin brasses.**—Made of composition, lined with white metal, and are used to connect the connecting rods and crank pins.

15. **Crank shaft.**—Made of forged steel. The crank shaft and connecting rods convert reciprocating motion into rotary motion, and transmits this rotary motion to other shafting and to the propellers which propel the ship.

16. **Drain cocks.**—On each cylinder are found packed drain cocks so placed as to drain the cylinder completely. These cocks are worked by levers from the working platform and discharge through a pipe into the fresh-water side of the condenser, sometimes into the hot well.

17. **Dead plate.**—The bottom of the furnace-door opening.

18. **Engine frames.**—They are made of forged steel and are used to support and to hold the engine and its parts together.

19. **Eccentrics.**—The larger part is made of cast iron and the smaller part of cast steel. They move the valves through the intervening parts of the valve gear.

20. **Eccentric straps.**—They are made of composition and are lined with white metal. They are used to convey the rotary motion from the eccentrics to the reciprocating motion of the valves.

21. **Eccentric rods.**—These are high-grade machinery forgings. They transmit motion from the eccentric straps and eccentrics to link blocks.

22. **Front and back connections.**—The space between the up-take doors or connection doors and the boiler, extending over the area covered by the tubes, is generally called the front connection in return-tube boilers and the back connection in direct-tube boilers. In Babcock & Wilcox boilers the doors giving access to the headers are called front and back tube doors.

23. Firing tools.—These are—

1. Shovels, which need no explanation.
2. Long and short hoes: These hoes are made heavy for working and cleaning the fires, the long-handled ones for reaching the back parts of the furnace. The lighter hoes are for use in hauling the ash pans.
3. Devil's claw: This is something like a heavy rake and has several claws on it. Most firemen prefer to use a hoe. It is used for working the fire on the grate and for removing clinkers.
4. Long slice bars: These are round bars with one end flattened, and are used to break up the clinker at the back of the furnace.
5. Short slice bars: Same as above, but are made shorter for convenience in working the fires at the front part of the grate.
6. Prickers: These are round bars with one end flattened and turned up. Stops are welded to some of these bars to prevent them entering the fire too deeply.

24. Furnace front and furnace doors.—The structure that closes the furnace opening is called the furnace front and in it are the furnace doors.

25. Grate surface.—This is the area of the fire grates.

26. Gauge cocks (or try cocks).—These cocks are fitted on boilers in addition to the water gauges, and an experienced man can tell, from the water that blows through them when open, where the water level is.

27. Heating surface.—All surfaces that are exposed to the heat and which are capable of transmitting the heat of the fuel to the water or steam are called heating surfaces.

28. Hydrokineter.—This apparatus provides a means of producing circulation in the boiler and hence shortens the time necessary for raising steam. Steam is admitted through the auxiliary line and is circulated through the water in the boiler. Used only on Scotch boilers.

29. Jacking engine.—This is a small double-acting engine fitted with differential valve gear in each engine room. It turns a worm wheel on the shaft of the engine by means of worm gearing. This engine is used to turn the main engines each day that they are not in use, called "jacking over the main engines." This is done each day the main engines are not used and they are turned over $1\frac{1}{2}$ turns.

30. Line shaft.—This shaft is made of forged steel. It transmits the rotary motion from the thrust shaft to the stern tube shaft.

31. Link blocks.—These are high-grade steel machinery forgings. They transmit motion from the links to the valve stems.

32. Lubricators.—Cast-brass oil boxes secured in parts of the engine at convenient points and have connections for distributing

the oil to the various bearing surfaces. The distance pipes lead to wipes on the moving parts and tubes in the bearings and guides. Each connection has a wick feed in addition to the sight feed.

33. Lazy bar.—To lighten the work when using long hoes in cleaning fires and in hauling ashes, a removable bar, called a "lazy bar," is placed in supports fitted to the furnace doorframe and to the ash-pit door.

34. Main bearings.—The caps and shoes of these bearings are made of cast steel and the brasses of composition lined with white metal. They form a bearing for the crank shaft.

35. Main steam pipe.—This is made of seamless drawn steel and is used to convey the steam from the boilers to the engines.

36. Main valve chest.—This is made of cast iron and is used to contain the main engine valve with the steam that is to be admitted to the cylinder.

37. Main links.—High-grade machinery forgings. They transmit motion from the eccentric rods to the link blocks.

38. Pistons.—Some are made of cast iron, others of cast steel. The steam pressure applied to them inside the cylinders moves them up and down. They are fastened to the upper end of the piston rods in a vertical engine.

39. Piston rods.—They are made of high-grade machinery forgings and transmit the up-and-down motion to the crossheads connecting rods and thence to the crank pin.

40. Propeller shafting.—Same as stern tube shafting. It carries the propeller and transmits the rotary motion from the stern tube shafting to the propeller.

41. Piston valves and slide valves.—These valves used to regulate the admission and exhaust of steam to and from the cylinders.

42. Priming or foaming.—This consists of water becoming mixed with the steam and passing over with it to the engines. It may be caused variously—

1. By insufficient room in the boiler for making steam.
2. By dirty water in the boiler.
3. Greasy water.
4. By carrying the water level too high.

5. From forcing the boiler; i. e., if the engines are taking more steam than the boilers can make, water is liable to be carried over with the steam. When raising steam care should be taken not to open the boiler stop valves too soon, and boilers should not be cut in on the main steam line until each individual pressure is at least 5 pounds higher than that in the line.

43. To remedy priming.—Throttle down the engines; close dampers; put on more feed; use the surface blow to remove the dirty

water from the surface of the water in the boiler. However, the first step is to first ascertain the cause for the boiler priming. If it is from salty water, the bottom blow should be used and the water freshened up by fresh feed. When a boiler primes it will be noticed that the water in the water columns is bubbling up and down—foaming.

44. Reducing valves.—These are special valves fitted in the steam lines to auxiliaries, where it is desirable to use a lower pressure than that in the boilers and to have a constant pressure independent of the fluctuations of the higher pressure in the boilers.

45. Spring bearing.—The pedestal of the bearing is made of cast iron, and the bearing of brass composition lined with white metal. It is used to support the line shafting.

46. Stern-tube shafting.—This shafting is made of forged steel, covered with composition water-tight castings made in sections that are shrunk on and pinned. This shafting transmits motion from the line shafting to the propeller shafting.

47. Stern-tube bearing.—This bearing is made of composition and is fitted with lignum-vitæ strips to form a bearing for the stern tube shaft.

48. Separator.—This is a guard against the entrance of water into the main engine cylinders. The steam on entering the separator is whirled around, producing centrifugal motion, which throws the particles of water out of the steam, which is then forced upward by deflection and out of the separator in a drier condition.

49. Sight-feed cups.—These are for supplying a steady and definite amount of oil to the moving parts and are so arranged that the number of drops of oil passing per minute can be counted. The oiler regulates the number of drops from experience, the amount depending on the speed at which the moving parts are moving and whether or not it is running cool.

50. Spring safety or relief valves.—To each end of each cylinder is fitted a spring relief safety valve, and to prevent the escape of hot water these valves are fitted with easily disconnected drain pipes leading to the bilge or hot well. At each connection of the auxiliary exhaust pipe to the condenser a stop valve and a spring relief valve opening toward the condenser are fitted, the purpose of the relief valve being to regulate the pressure of the exhaust steam when it is used in the low-pressure receivers or feed-water heaters.

51. Sentinel valve.—This is a spring safety valve and is set to blow at a pressure about 5 pounds less than that for which the boiler safety valves are set. These valves are sometimes fitted to each boiler.

52. Surface-blow valves.—One-inch valves bolted on near the front of each boiler and closing against the boiler pressure, by means of which the dirt and grease may be blown off the surface of the water in the boiler.

53. Slicing doors.—A small opening cut in the furnace door permits the use of a slice bar, without having to open the furnace door, and this opening is covered by a heavy-hinged slicing door.

54. Salinometer.—This apparatus is attached to every shell boiler and tubulous boiler for the purpose of ascertaining the concentration of the water inside the boiler. Salinometers are not now fitted.

55. Steam traps.—To prevent the waste of fresh water, drain pipes are lead into automatic traps, which discharge into the feed tanks or condensers.

56. Thrust shaft.—This shaft is made of forged steel. It receives motion from the crank shaft and transmits this rotary motion to the line shaft and the propeller shaft. It has collars on it which work in the thrust bearing, taking up the thrust along the shafting from the propellers, preventing the thrust acting on the main engine itself.

57. Thrust bearing.—(See description of main engines.)

58. Throttle valve.—This valve is made of cast steel and is used to regulate the supply of steam to the engines.

59. Thermometers.—For taking temperatures are fitted as follows: One on each hot well, one in each feed tank, one on each feed pipe in the engine room near the discharge from the feed heaters, one on each main injection pipe, one on each outboard delivery pipe, and one on each feed pump. The use of thermometers for taking the temperature of the oil that is circulating around bearings is necessary with forced lubrication.

60. Valve-chest liners.—Made of close-grained cast iron as hard as can be worked. They form a working lining for the valve chests, and guides and bearing surfaces for the valves.

61. Valve stems are high-grade steel machinery forgings and transmit motion from the valve gear to the valves.

62. Valve stem crossheads and guides.—Used for connection and guide to the valve stems.

63. Water service.—A water service connected with the sea has branches fitted with valves leading to the various guides, bearings, and moving parts of the engines.

64. Draft.—What is induced draft? How does it differ from forced draft?

Answer. Induced draft is the drawing from the boiler of the hot gases with the consequent drawing in of the air. This draft is

occasioned by fans in the boiler uptakes at the base of the funnel, worked by engines placed on the boiler wings.

Forced draft is the forcing in of air into the fires, either by putting air into an air-tight fireroom by fans in the cowls (ventilators) or forcing air into a closed ash pit under the fire without pressure in the firerooms. The closed fireroom system is the best. For connection between compartments the air locks previously described are employed.

65. Boiler losses.—Point out the losses that may take place during the combustion of coal in a marine boiler. What steps are taken to prevent these losses?

Answer. Sources of waste:

- (a) Waste by radiation and conduction.
- (b) Hot gases leaving funnel.
- (c) Waste of coal in smoke and ash.
- (d) Solid unburnt fuel leaving funnel or in ash.
- (e) Air leaks in boiler casing.

Prevention:

- (a) This may be greatly reduced by good lagging.
- (b) Use the upgoing hot gases to heat feed water and also to heat the air going to the furnaces.
- (c) Regulate the air supply.
- (d) Must be reduced by even and good firing.

66. Hydraulic test.—Describe the process of water testing a cylindrical boiler. State how you would prepare it for the test, how pump it up, and what observations you would make during the test.

Answer. The boiler can either be tested by hand or by a steam pump. If the latter is used, however, all connections between boiler and any pipe containing steam must be blank flanged. When the load is approximately 90 pounds we test to double the working pressure, and reducing from thereon according to the pressure specified in the Navy Regulations.

A good method: 1. Gag the safety valves and see the stops properly closed. 2. Fix deflection meters in furnaces, combustion chambers, and in any other part of the boiler considered necessary. The meters should register zero before any pressure is applied. See water in boiler free of air. 3. Pump up to the required pressure and see if the pressure is held. Note meters carefully, and go over all seams to ascertain if there are any leaks. Carefully examine all tube ends for leaks. 4. Let the pressure back, and try the meters to see if there is any permanent set to any of the parts.

PART III.

GENERAL DIVISIONAL DUTIES.

SECTION 1. ROUTINE IN PORT.

(a) On arriving in port after having been to sea the routine consists of making adjustments, repairs, and examinations of all the machinery in the engineer department. During the run at sea the repairs necessary to be made on arrival in port are noted, and a list of these repairs is posted in each engine room with the time allowed for making them. The extent of these repairs depends on the length of stay in port. The morning watch is generally devoted to cleaning bright work, moving all machinery that is not in use or not disabled for repairs. All levers, valves, cut-off gears, and the links are moved each day. The main engines are jacked about one and one-quarter turns, and care should be taken to see that the links are in full gear, in order that the valves may be moved at the same time. The engine-room bilges are washed out with scalding water after the main engines are secured; all the oil and grease must be removed. All strainers are taken out and cleaned. All parts of the engine are wiped off, while the lather formed by the oil is soft and easily removed. The main thrust bearings are washed out thoroughly and cleaned, then covered with a piece of canvas to keep out dirt. If, during the run, any bearing has been running hot or loud knocking has been occasioned, the bearing must be adjusted. "Leads" are taken and the amount of clearance determined. In taking leads the following steps are followed:

1. Remove the cap, top brasses, and liners.
2. Lay soft pieces of lead wire at about equal intervals across the journal at right angles to the axis.
3. Replace the liners, top brasses, and caps.
4. Screw down hard and equally on the nuts compressing the lead wires. When set up hard and evenly the nut and journal are marked, in order to make the adjustment after removing the leads.
5. The cap, brass, and liners are removed and the flattened parts of the leads measured by micrometer gauge. The bearing is then adjusted and refitted by scraping or filing down the high places on the babbitt metal until the desired clearance is obtained.

The cylinders are opened and their interiors, which should be bright and have a good polish, are carefully examined for ridges,

and then given a light coating of cylinder oil or vaseline, before they are closed. Care is taken not to close up the opening to the relief valves.

(b) In the firerooms while in port the double-bottom compartments, bilges, and coal bunkers are inspected, and, if necessary, scaled and painted or red-lead. All fittings to the bunkers, such as water-tight doors, bunker plates, valves, and fire-extinguishing apparatus and fittings for ventilation, are overhauled and examined. The boilers are cleaned and, if necessary, scaled. The tubes are swept and, when necessary, turbined. A "turbine" for tubining tubes is composed of cutters made to revolve by water pressure. These turbines are connected to a water hose and shoved through the tubes, the turbine's revolving cutters eating their way through the scale and grease deposits on the tubes. The grate bars are removed and all slag and clinker cleaned off, badly burned bars being replaced by new ones. The ash pits, furnaces, combustion chambers, and outside plating are all cleaned and, where necessary, scaled and red-lead. In order to soften the grease, scale, and salt deposits (if any), a steam jet or the use of small amounts of kerosene are good. All tube sheets, crown sheets, tubes stays, rivets, and seams are examined for leaks and for pitting. Where weakness is noted the parts are renewed. When ready to scale a cylindrical boiler the drains are opened, man and hand hole plates removed, and the air inside the boiler tested by a flame to see if it is fresh. All internal fittings, after scaling is finished, such as "zincs," dry pipes, internal feed pipes, all supports, braces, etc., having been examined, cleaned, or renewed where necessary, the refuse is removed from the bottom of the boiler. The boiler is then given a thorough washing out. Gaskets for all plates are examined and renewed where it is necessary. The cleaning is then continued by giving the boiler a boiling out with boiler compound or soda. After this the boiler is allowed to cool, then emptied and all deposits at the bottom removed, and the boiler is filled with fresh water. The water tender in charge sees that the boiler is secured and makes a report to that effect to the engineer officer having the day's duty.

(c) Generally, every other Wednesday afternoon, bags are inspected. The clothes should be neatly rolled up and stopped. The bag should be laid out in uniform manner, the blue uniforms in a straight line on one side with pea-jacket, socks, jersey, and flat hat; beside them in a parallel line, the white uniforms, underwear, and white hats. When ready for inspection each man must stand up at attention to the right of his bag. Section leaders should see that the bags in their sections are laid out systematically in

parallel lines and that the clothes are laid with the name up. At hammock or bedding inspection the blankets are folded name out at one end of the hammock. The mattress cover is turned back showing the man's name on the mattress. The lashing must be coiled down neatly.

SEC. 2. STEAMING WATCHES AND ROUTINE AT SEA.

(a) RAISING STEAM AND GETTING READY TO GET UNDERWAY— COAL-BURNING BOILERS.

The following is the procedure:

1. The number of boilers to be used and the time of getting underway will be given, also the time of lighting fires.

2. Previous to the above time a general examination of the boilers and all attachments, such as gauge glasses, should be made and everything put in readiness for getting up steam.

3. Pump boilers to steam level, keeping the air cock open to allow the escape of air until steam has formed.

4. It is the duty of the coal passers to get the coal out and place it in front of the furnaces of the boilers to be used. The firemen, when they receive the order, "prime" the furnaces—i. e., cover the grate with a layer of coal from 4 to 6 inches and within a foot of the dead plate. The water tenders see that the gauge lights are in order and burning, that the furnaces and ash-pan doors of boilers not to be used are closed, and that their main feed and check valves, also their boiler stops, are closed. They have coal and broken wood piled in the furnace mouth, to be lighted with a handful of waste if there is no other boiler in use for auxiliary purposes; otherwise the fires are lighted by shovelful of live coals from the boiler in use.

All water tenders are cautioned not to prime furnaces until the boiler is pumped up to steaming level.

5. With Scotch boilers five or six hours are taken for raising steam, and with tubulous boilers two hours are generally consumed, except in case of great haste, when steam can be raised inside three-quarters of an hour. If the boilers are fitted with hydrokineters they are started as soon as or a little before fires are lighted, steam being taken from the auxiliary boilers. If they are not fitted, in emergency, circulation may be assisted by drawing the water from the bottom of the boiler and returning it through the feed pipe by means of an auxiliary feed pump.

6. While the boiler is warming up keep the air cocks open until steam has formed and is blowing through them. Keep the furnace doors ajar and the ash-pit doors partly open. As the coal becomes

partly ignited, shove it back from time to time with the hoe, mixing it with the green coal at the back, supplying fresh coal in front. Keep the fires leveled off, and as bright patches show cover them with coal. Keep the fires back from the dead plate to avoid burning the furnace-door liner. Also it is a bad plan to heap coal in the back part of the furnace as it kills the draft.

7. As soon as steam forms the water tender reports that steam has formed on such and such a boiler. As the steam is rising in pressure the water tender has all drains that are blowing steam closed, the air cocks are closed and the safety valves are closed if they have been used in place of the air cocks and the steam pressure is allowed to rise. The safety valves are set and tested for the pressure required. The machinist mate, second or first class, who is detailed to scout up all leaks and remedy them, sets the safety valve at the desired pressure. The water tender allows steam in his boilers to rise until the safety is correctly set and then stands by with a pressure about five pounds below the safety valve setting.

8. As soon as the safety valves are set the boiler stop valves are opened wide, very slowly, cutting the boiler in on the main steam line which has been previously warmed up by having the boiler stop valve slightly cracked, by the use of steam from the auxiliary steam line, or by the use of the by-pass on the bulkhead stop valve on the main steam line. The boiler should not be cut in on a main steam line already under steam until the boiler pressure is about 5 pounds above the main steam line pressure. The water tender now reports that he is ready for getting under way to the engineer officer of the watch.

(b) WARMING UP—RECIPROCATING ENGINES.

[See part 1, section 11. Preparations for getting underway.]

1. A general examination to see that everything is ready and that the engines are clear of tools, etc., is made.

2. As soon as steam is reported from the firerooms as having formed start up the main circulating pump as follows:

1. Open the steam exhaust and drains.
2. Open the discharge to the main condenser.
3. Open the main injection.
4. Admit steam slowly to circulating pump engine, warming it up and running it slowly.

Then start up the main air pump as follows:

1. Open the steam exhaust and drains.
2. Open the suction from the main condenser.
3. Open the discharge to the hotwell or feed and filter tank.

4. Open the steam valve slowly, warming the air pump engine up slowly, and keep an eye on the vacuum gauge to see that all is running right. The main condenser is now ready to receive the exhaust steam, and the auxiliary exhaust may be turned into it. Shut down the auxiliary condensers when the main are taking care of the exhausts.

3. Open the main stop valve, bulkhead stop, having previously warmed the line by cracking the by-pass, and bring steam up to the throttle.

4. Commence warming up the engines through the jackets. For this purpose a small line is lead from the main steam line called the "jacket line."

5. Put in the wicks. Start sight feed about eight drops per minute.

6. See cylinder drains open.

7. If in a hurry to get warmed up open the by-passes to the receivers from the main line and warm up by admitting live steam to the cylinders.

8. See that the stern tube gland is slacked back and that the worm from the jacking engine is disconnected.

9. Admit steam to the reversing engine and see that its cylinder is well drained.

10. Open the suction and discharge to the shaft bilge pump.

11. Everything is now in readiness for trying the main engines, which is done about 15 minutes before the time set for getting underway. Get permission from the officer of the deck to turn over the main engines, and having received such permission, proceed as follows: The throttle is opened slightly and the links thrown over. Work the links back and forth until the engine starts. Be careful not to keep the engine turning in the same direction too long; avoid getting way on the ship. A good plan is to run one engine ahead and the other astern, changing together. The water in the cylinders should be gradually worked out through the cylinder drains. When satisfied that all is ready and the engines thoroughly warmed up, close the main-engine throttle valve and put links on the center. Now report to the officer of the deck, "Main engines ready for getting underway."

12. Stand by for a "signal."

Getting underway with boilers using oil fuel is very similar to the above, except that oil is used instead of coal and the manner of lighting fires (burners) and using oil is discussed under the section describing oil-burning boilers.

(c) DUTIES OF A STEAMING WATCH IN THE FIREROOMS WHEN BURNING COAL.

1. No matter how the speed of the engines is varied endeavor to keep the steam at a constant pressure and to maintain a constant steaming water level. The water tender will be advised in advance of all changes in speed and should check or force the fires as occasion arises. The firemen should fire regularly and evenly and use the slice bar as little as possible.

2. **Firing a furnace.**—All large seagoing ships now have the standard time firing device, which at set intervals shows a light indicating the number of the furnace that is to be fired, and the furnaces are fired in rotation. This has been described in section 13, part 1, "Working the fires—Time firing." The coal passers get out the coal, which should be spread evenly over the fire in order that every square foot of grate surface may be used, and each shovel full of coal should be spread over as much surface as possible. The fireman must take care that no holes occur at the back or sides of the furnace. This will be acquired by practice and training; water tenders should assist the firemen in becoming skilled in doing it. The fires should be carried at a uniform thickness of from 5 to 8 inches, under natural draft, a little heavier at the back of the grate and along the corners and sides keeping the middle leveled off even, and the fire bright all over. Firemen should take pride in not having smoky fires. To avoid this do not allow the coal to coke banked up in the front of the furnace, and then shove it back. This causes the formation of heavy clinker, and thus makes cleaning fires much harder. On opening the furnace door the fireman should look for the spot needing coal and not heave in a shovel full blindly. The places that have burned down to a dull red need a moderate supply of coal, those that have burned white need a sprinkling of coal, those places that are giving off smoke and flame are not ready for more coal. Slicing the fires should be done only occasionally in order to break up the clinker. The use of the slice bar not only causes a waste of coal, but makes more work for the fireman himself, for *by wasting it he has to supply more himself*. Keep the fires light, fire regularly and evenly, and the hard task of cleaning fires is much lightened.

3. **Cleaning fires.**—Fires are cleaned in rotation every 12 hours, and the extent of the cleaning will depend on the amount of the slag and clinkers on the grate bars. The front connection doors are sometimes marked with chalk, showing in what watch the fire is to be cleaned. The fire is allowed to burn down, is kept at an

even level, and the formation of holes avoided. The water tender should so regulate his water level that after the fires are cleaned and are coming up he may slow down his feed, and thus quicken the formation of steam and make it more regular. The coal passer leads out the hose and stands by to wet down the ashes. The damper is partly closed and with the hoe the fireman shoves the good fire on one side over to the other side. This leaves the clinker on that side exposed. He hauls the clinker out of the furnace with the rake or hoe and if it sticks to the grate bars the slice bar is used to loosen it. The coal passer wets the refuse. The good fire is now transferred back and the clinker left bare on the other side. This is hauled out and the good fire remaining is spread evenly over the entire grate. This good fire is now sprinkled with fresh coal, the damper is opened, the water tender slows down his feed and the fire is allowed to come up. An alternative method is to push the fire from one side to another. The coal passer now hauls the ash pans, being careful not to wet any part of the boiler when he floods them after getting the ashes out. On a long run the ashes and clinker will be found to settle more or less on the tubes and it becomes necessary to "sweep tubes." The connection doors are opened, having first closed the ash pit doors if the draft is great, and a flexible hose providing a steam jet is used for the purpose. Brushes are sometimes used but take longer. As soon as the watch comes on it is customary, on some ships, to start in cleaning fires. The fires are cleaned at intervals, and at different times, but all fires should be cleaned and ashes ready for hoisting by six bells; it is five bells on some ships. The fireroom floors should be swept up as clean as is consistent; and the coal for each hour should be got out at a quarter to the hour, keeping accurate count of the buckets as well as of the buckets of ashes. The water tender must keep the water level constant and if oil shows in the water column glasses the boiler should be given a slight surface blow. **The bottom blow to boilers should never be touched unless in obedience to an order from the engineer officer of the watch.** The strainers in the firerooms must be kept clean and clear. At the end of the watch, or about seven bells; coal must be got out for the relief watch, and the fires that are next to be cleaned should be allowed to burn down.

4. To disconnect a boiler.—Allow the fires to burn down slowly, keeping them leveled off. Close the ash pit doors partly and watch the steam-pressure gauge. As the pressure falls partly close the boiler stop valve. The self-closing boiler stop valve as shown in sketch No. 8 will generally take care of the steam, but it can not be entirely depended on as the drop in pressure is gradual. When

steam has ceased to form, close the main feeder valve and the boiler stop valve and shut off the feed. Give the boiler a slight surface blow to remove any oil or grease on the surface of the water. When the fires are dead, the furnaces are hauled and the ashes made ready for hoisting the next time.

(d) DUTIES OF A STEAMING WATCH IN THE ENGINE ROOM.

The duties of each man are stated in detail in Part I. The machinist's mate of the watch observes the running of the engines, receives and makes reports, and keeps data up to date in the log. He keeps the water tender informed of every change in speed, and when maneuvering in squadron keeps the cut-offs well run out. He sees that each man does his duty. When coming into port notice is generally given one-half hour ahead of time, and the water tender must be notified. When given permission to secure the main engines the following procedure is carried out:

1. Knowing what repairs are to be made, the engines should be stopped at the most convenient position. The bulkhead stop valves are closed and the cylinder and valve chest drains are opened.

2. In the firerooms the fires are allowed to die out in all boilers except those to be kept for auxiliary purposes. The ash-pan doors are partly shut and the dampers closed. When the fires are dead and the boilers are cooled off the furnaces and ash pans are hauled.

3. The wicks are taken out, and the oil cups and manifolds are well cleaned with hot water and a little soda.

4. Set up on the stern gland.

5. Slow down the main air and circulating pumps until the pressure in the boilers has fallen and the engine is well drained. Then shut them down, connect the auxiliary exhaust to the auxiliary condenser, and shut the outboard delivery valves; to shut the main condenser down do in reverse order what is done on starting.

6. Wash out the bilges with scalding hot water from the boilers and wipe all the oil lather from the engine parts.

7. Clean out the main thrust bearings and cover with canvas to keep out dirt.

8. Oil all bearings and then plug up holes with waste.

9. Close the suction and discharge of the shaft bilge pump and clean out all strainers.

10. If any bearing has had water used on it that bearing must be overhauled at the first opportunity.

11. When secured, report to the officer of the deck, "Main engines secured."

SEC. 3. CASUALTIES LIABLE TO OCCUR—CAUSE AND REMEDY.

1. **Collapse of furnace crown in Scotch boilers.**—(a) This is generally due to the overheating of the plate, caused by carrying the water too low or from oil and salt or scale deposits.

(b) Allow fires to die down, unless the collapse is complete, when it may become necessary to haul fires.

(c) Disconnect the boiler, and as soon as it has cooled down make an examination.

(d) If the crown is only bent, jack it back into place; if the crown is carried away, a new one must be put in place.

2. **Leaky tube, burst tube, in Scotch boilers.**—(a) Plug the tube up with a tube stopper or with a pine plug.

(b) This is generally due to the pitting of the metal or the splitting of the tube. It should not be necessary to haul fires in a cylindrical boiler.

3. **Leak in gland.**—To stop a leak in a gland, set up on the nuts. If the leak does not stop disconnect the line and renew the packing.

4. **Burst gauge glass.**—(a) In the case of a Scotch glass close the upper end by the chain gear from the fireroom floor, take out the old glass and put in a new one. Open up the connections to the boiler.

(b) To remove the glass as fitted to some Scotch boilers, close the valves K and L, sketch 24.

(c) When a Klinger gauge glass goes, the glass is disconnected and taken down.

(d) Come up on the nuts and take out the old glass.

(e) Obtain an order from the engineer officer of the watch for a new glass. New glasses come packed in a pasteboard box with a sheet of asbestos.

(f) Smear the edges of the metal case with white lead or, what is the same thing, white zinc, and lay the sheet of asbestos on it.

(g) Insert the glass and cut the asbestos out around the line of the glass.

5. **Loss of vacuum.**—Causes:

(a) Faulty action of the valves or the carrying away of the valves.

(b) Air leaks in the condenser.

(c) Too much clearance space between the bucket and foot valves at the end of the stroke.

(d) Cock in the connecting pipe to the vacuum gauge partly closed or a leak in the pipe.

Remedy:

(a) The main engines will have to be stopped and the pump overhauled.

(b) It is sometimes possible when steaming at slow speeds to use the pump in the other engine room or the hot-well pump to maintain the vacuum until the main air pump can be repaired.

6. **Hot bearing.**—Causes:

(a) Insufficient oil supply, due to either faulty design or neglect of duty of the oiler.

(b) Dirt or grit in the bearing. The presence of dirt can be discovered by the color of the oil and from particles of grit seen in it.

(c) Not enough clearance space, bearings not in proper adjustment, or bad fitting.

(d) The brases not set square.

To cool:

(a) Increase the oil supply and turn on the water service. See water service not clogged up.

(b) If this has no effect, slack back on the bearing nuts a little bit and apply a solution of soft soap, oil, and water through a syringe.

(c) Overhaul the grease pots and put in a mixture of finely ground graphite and grease.

(d) If the bearing becomes hot, slow down the engine and cool it with an application of oil. Cold water should never be used on a bearing which is very hot, as it is liable to crack it, due to the rapid contraction. Cool the bearing first and then in an emergency keep a small stream of running cold water playing on the *outside* of it.

EMERGENCIES IN THE ENGINE ROOM (U. S. S. "UTAH" AS EXAMPLE).

8. Leak in main steam pipe:

A. Close stop valves either side of leak if bad; let fires die out in boilers, discharging steam into leaky section.

9. Main condensers lose vacuum:

A. See pressure on steam glands and leak off properly regulated; see that main circulating and air pumps are running; examine all joints for leaks; examine vacuum gauge and connections and see that it is not shut off.

10. Main condenser heats:

A. Speed up circulating pump; examine suction and discharge pipes and see that valves are open; injection may be clogged; blow out with steam.

11. Main condenser circulating pump stops:

A. Stop main engines and notify bridge and senior engineer officer; close all main injections; open main drain valves and try running by having pump in other engine room take its suction through condenser via main drain, or allow water to back through

the condenser and discharge into engine-room bilges through main drain connection; then keep bilge clear by means of bilge pumps; this does not affect the other engine room; suction might also be created by putting the bilge pumps on the main drain through the circulating and rear manifold.

12. Feed water heater leaks:

A. If serious, cut out heater and repair.

13. All main feed pumps break down:

A. Notify water tender; start auxiliary feed pumps and cut out main feed line in each engine room.

14. Losing propeller:

A. Stop main engines.

15. Turbine strips blades.

A. Stop main engines on affected side.

16. Water in feed tanks becomes too hot:

A. Look for drain blowing into tanks and see if air-pump discharge is cool.

17. Fires in fuel oil double bottom:

A. Turn on steam for smothering fire; considerable oil can be pumped out through suction until pump will not handle it; get water down through vent pipe if possible; use chemical fire extinguisher.

18. Steam pressure falls:

A. Decrease firing interval and if necessary start forced draft blowers.

19. Make up feed-pump breaks down and water needed:

A. Open reserve suction to main feed pumps; open reserve feed suction to main air pump.

20. Gland steam fails:

A. See main gland valve open and reducing valve working properly; try taking steam from pockets of cruising turbines through gland line; that is, let the high pressure leak off, past the low-pressure glands.

21. Break down in either starboard or port fuel oil supply pumps, or both:

A. Shift to other pump. If both break down, repair at least one before all settling tanks are empty.

22. Oil pressure in fireroom fails:

A. See settling tanks filled and suction valves open.

23. Lubricating pumps become too hot:

A. Speed up oil cooling pumps and if necessary start other pump.

24. Bearing overheated:

A. Speed up forced lubrication and oil-cooling pumps, see bearing has proper oil supply, examine gland for any excessive steam leakage.

25. Lubricating oil pump breaks down:
A. Use gravity tanks until supply is exhausted and then shut down main engines; repair at once.
26. Lubricating oil cooling pumps break:
A. Use fire and bilge pump, through connection for this purpose.
27. Shaft breaks:
A. Stop main engines.
28. Steering engine breaks down:
A. Steer by hand.
29. Leak in fuel-oil settling tank:
A. Empty tanks and repair leak; see bilges clear of oil.
30. Gauge glasses blow out on separator:
A. Close gauge valve cocks and renew glass.
31. Air pump breaks down:
A. Use other pump through cross connection or use channel way suction to main feed pumps.
32. Dummy clearances become dangerously low:
A. Take clearances every few minutes. If necessary slow or stop and try shifting combination to force rotor out. An increased receiver pressure on any turbine will tend to force the rotor out.
33. Water very low in feed tank:
A. Take make-up feed. Make examination for cause.
34. Lubrication oil drainage tank leaks:
A. Repair leak and fill tank to working level.
35. Feed tank overflows:
A. Run water back into reserve bottoms.
36. Fire quarters sound:
A. Start additional fire and bilge pumps and close water-tight doors.
37. Collision quarters sound:
A. Close water-tight doors and be prepared to pump out flooded compartments.
38. Abandon ship sounds:
A. Send all men out of engine room except those absolutely necessary.
39. Engine room traps do not work:
A. Close and by-pass trap and repair.

EMERGENCIES IN ENGINE ROOM DURING BATTLE.

40. Port engine room bilges flooded:
A. Pump out same with fire and bilge or main circulating pump, if necessary stop turbines on that side; run other engine independently; close necessary bulkhead stops.

41. Starboard settling tank punctured:
 - A. When tank is empty, use other tank and pump oil out of bilges.
42. Main steam line in port passageway punctured:
 - A. Close bulkhead stop No. 3 fireroom and haul fires boilers 10 and 12; close cross connection to port engine room, and cross connection to No. 3 fireroom.
43. Engine room telegraph out of commission:
 - A. Station man at speaking tube to central station.
44. Shaft alley flooded:
 - A. Pump out same with fire and bilge pump.
45. Fireroom passageway flooded:
 - A. Close water-tight doors in fireroom and in passage.
46. Main condenser punctured:
 - A. Stop main engine on injured side; see auxiliary exhaust cut-out of that condenser.
47. All starboard air compressors out of commission:
 - A. Cut out starboard and use port compressors.

EMERGENCIES FOR AUXILIARY WATCH.

48. Leak in main steam line, port:
 - A. Close bulkhead stop, No. 3 fireroom port, and close stop in port engine room outboard.
49. Leak in main steam line, starboard:
 - A. Same as above, starboard for port.
50. Auxiliary condenser loses vacuum:
 - A. Speed up air and circulating pump; look for leaks and, if necessary, shift to other side.
51. Auxiliary condenser heats:
 - A. If in use speed up air and circulating pump; if not in use start same until cooled off; see spring-loaded valve closed.
52. Auxiliary air and circulating pump stops:
 - A. Tap valve lightly with wrench, and if unable to start shift to other condenser; examine steam and exhaust valves and see whether nuts on valve stem are in proper position.
53. Both auxiliary condensers unavailable:
 - A. Use main condenser; start main air and circulating pump; open main injection and overboard discharge; start feed pump on other side.
54. Feed-water heater leaks:
 - A. Shift to other side and repair leak.
55. Evaporator discharge to feed-water tanks leaks:
 - A. Shut down evaporator and repair leaks.

56. Evaporator discharge to fireroom tanks leaks:
 - A. Shift evaporators to ship's tanks or shut down and repair leaks.
57. Feed and filter tank becomes too hot:
 - A. Look for drains blowing; examine discharge from auxiliary air pump; speed up circulating pump.
58. Feed water reading drops, showing a leak:
 - A. Examine main feed line for leaks; if found, shift to auxiliary feed and repair leaks.
59. Reserve feed-water tank overflows:
 - A. Shift to another bottom; if all tanks are filled shut down evaporators or shift to ship's tanks.
60. Starboard main feed pump breaks down:
 - A. Use feed pump on port side and shift to port feed-water heater, securing starboard pump and heater.
61. Leak in fuel-oil bottom, double, C-94:
 - A. Pump it out of bottom as rapidly as possible.
62. All electric lights go out:
 - A. Light oil lamps for gauges, gauge glasses, etc., and call dynamo-room watch.
63. Make-up feed pump breaks down and needs water:
 - A. Use main feed pump on reserve bottoms.
64. Large leak in engine room or fireroom and fire and bilge pumps fail to keep down the water:
 - A. Start main circulating pump and open main drain.
65. Oil overflowing on deck from settling tank vent:
 - A. Shut down pump; run oil back into bottom until tank is filled to proper level.
66. Vapor coming out of after escape pipe:
 - A. Look for leaks in safety valves and for steam traps blowing steam into feed tank; water in feed tank may be too low.
67. Vapor coming out of forward escape pipe:
 - A. Examine safety valves for leaks and examine dynamo hot well for excessive heat.

BOILER-ROOM CASUALTIES.

68. Unable to keep steam:
 - A. Be sure all dampers and ash-pit doors are opened and fires are in good condition; start blowers to assist draft; notify engine room to keep temperature of feed water as high as possible; have time firing interval decreased and fire lightly; fires that are in need of cleaning the worst should be cleaned as soon as steam can be held; then start blowing tubes and, if necessary, haul soot boxes; the cleaning of fires, blowing of tubes, and hauling of soot boxes should

be done gradually, so that steam can be held; evaporators may be shut down for a short period.

69. Water out of sight:

A. See that feed and check valves are open; close ash-pan doors and dampers; use try cocks; open drain from bottom of water column and see if water or steam comes out; stop auxiliary machinery that can be temporarily spared; more force should be put on feed pumps; start auxiliary feed pumps; put out fires if water level does not show up quickly; fire up on other boilers to keep up steam.

70. Unable to run main feed pump:

A. Start auxiliary feed pump in steaming fireroom; if this is impossible start nearest auxiliary feed pump to steaming boiler.

71. Unable to run main feed pumps and auxiliary feed pump in steaming fireroom out of order:

A. Run auxiliary feed pumps in fireroom nearest steaming boiler on main feed line; shut cut-out valve on main feed line in both engine rooms; then connect discharge from auxiliary feed pump to be used to main feed line, and feed steaming boilers through main feed check and stop valves.

72. Failure of safety valve to work:

A. Lift safety valve by hand gear in fireroom or lifting gear from berth deck. If safety valve does not lift at desired pressure use hand gear to relieve pressure in boilers, and check combustion by using dampers and partly closing ash-pan doors, and if pressure still goes up put out fire with wet ashes.

71. Leaky safety valve:

A. Examine lifting gear to see if it is slack and free. If this gear is taut it probably is the cause of the leak. If valve still sticks lift with hand gear, then tap end of valve stem lightly; something may be under the seat, and lifting it will blow it clear.

72. Tube blown:

A. Notify engine room; see that dampers are closed. If necessary to clear firerooms of steam start blowers. Check combustion by closing ash-pan doors, extinguish fires with hose; also keep water in glass; cut out boiler by closing main boiler stop and keep feed stop and check valves open until fires are dead, then close them; put out fires first with wet ashes before hauling them; hauling fires increases the heat.

73. Manhole gasket blown out or handhole gasket blown out:

A. Send for boiler maker, as it may be possible to set up on the gaskets; make preparations for cutting out the boiler if it does not stop; check combustion and let boiler die out and disconnect same; make preparations for lighting up another boiler.

74. Boiler casing leaking badly:

A. Patch large leak with sheet iron; fill small leak with magnesia or asbestos paste.

75. Serious leak in fireroom bilge; fire and bilge pumps will not handle it:

A. Use engine-room fire and bilge pumps to assist fireroom fire and bilge pumps. If necessary start main circulating pump on main drain.

76. Burnt-out grate bars:

A. Push fire aside; tie new bar to slice bar and put in.

77. Water salty in boilers:

A. Test auxiliary condenser discharge, also dynamo air-pump discharge and water in reserve bottoms from which the feed is being used.

78. One oil pump stops running:

A. Start other oil pump; then examine pressure gauge, governor gear, drain, exhaust, suction, discharge, valves, and cylinder drain of pump that had stopped. If pressure gauge is high burners may be clogged or shut off.

79. Both oil pumps stop running:

A. Examine steam and exhaust lines to see that all valves are open; examine valve gear of pump; see suction and discharge valves open.

80. Burners (fires) go out:

A. Stop blowers; make preparations for burning coal. If oil can be supplied in short time, light burners.

81. Pressure falls in oil line:

A. Notify engine room; examine settling tank; speed up pump and if necessary start another pump; test pump by closing oil line discharge valve.

82. Oil on fire in fireroom floor plates or bilges:

A. Use sand or ashes kept in buckets for this purpose, also wet ashes from ash pans; also steam hose kept connected ready for this purpose. If fire is extensive, close oil-supply cut-out valve on berth deck or gun deck; shut off suction valve from settling tank and close doors.

83. Gasket breaks or blows on oil-supply pipes:

A. Use temporary patch or soft wood plugs if nature of break will permit. If fire is extensive, shift to coal at once.

84. Excessive pressure of oil:

A. Shift to filter strainers not in use; examine, clean, and renew, where necessary, strainers that are clogged up or worn-out.

85. Excessive temperature of oil:

A. Throttle down on steam valve to heater or partly close drain from heater.

86. Air pressure fails; flames shoot out into firerooms:

A. Decrease oil pressure either by shutting off burners or slowing down pumps until blowers can be speeded up to give sufficient air pressure. If blowers supplying air to ducts fail to run, close fireroom and start other blowers.

87. Man seriously injured:

A. Get doctor or steward; make preparations for removing him by way of engine room to sick bay; do not move man until medical assistance has arrived. Senior petty officer will make full and complete report of accident to engineer officer on watch for purpose of entering in log.

88. Lower bunkers empty difficult to supply coal:

A. Get men on watch that can be spared to trim coal to fireroom chutes, or such men that can be secured besides regular watch. One or two bunkers should be kept in reserve for hard steaming.

89. Boiler primes:

A. Reduce water to low steaming level and check combustion; notify engine room so that by-pass on separator traps can be opened; also open by-passes of main steam line traps.

90. Safety precautions in regard to newly opened bunker:

A. No bunker shall be entered from above without first lowering a lighted candle and note that it burns brightly for several minutes.

[NOTE.—Directions for remedying casualties apply for all cases underway, in port, or on auxiliary.]

SEC. 4. COALING SHIP.

1. **Preparations.**—(a) The amount of coal in each bunker is estimated.

(b) A coaling detail is made out with water tenders in charge of gangs of men working in the bunkers.

(c) An inspection is made of the bunkers to see that all buckets, chutes, shovels, barrels, and trolleys are removed.

(d) The coal chutes are rigged, bunker plates removed, coaling ports opened, and coaling screens rigged.

(e) All coaling tools are made ready, such as shovels, weighing scales, and trucks.

(f) All doors in the bunkers that are not required for passage of coal are closed.

2. **Coaling.**—The coal is dumped into the bunkers through the coal chutes by the deck force, and it is trimmed in the bunkers and properly stowed by the engineer force, the water tender reporting when their bunker is within a few tons of being full. After coaling, the temporary screens are removed and the coal chutes

are taken down. The bunker plates are replaced and made water-tight. All coaling tools are returned to the storeroom keepers and all hands start in cleaning ship on their cleaning stations.

SEC. 5. AUXILIARY WATCHES.

1. An oiler and two or three firemen are detailed to stand watch on the ice machines. They issue the ice only when ordered and are held responsible for the cleanliness of the plant. They are required to keep the ice-machine log, and record hourly the temperatures in the thermometer wells of the cold-storage compartments.

2. Two coal passers and two firemen are detailed for day's duty in the steam launches for each launch. They take day on and day off generally. At sea they are required on some ships to overhaul the steam-launch machinery and clean the machinery, getting it ready for service on coming to anchor. They watch the amount of coal and water in the steam launch, and when more is needed report same to coxswain. Steamers should as a rule be coaled and watered during the morning watch before breakfast. Steam-launch crews may have to stand steaming watches at sea; if not they should practice firing and prepare themselves for promotion.

3. Firemen stand watch on the evaporating and distilling plant. They are responsible for the cleanliness of the machinery and the evaporator rooms. An evaporator is practically a small boiler, except that steam is used instead of coal to evaporate the sea water. It has the following fittings: Bottom blow valves; gauge glass, safety valves; feed check valve, through which water is forced into the evaporator by the evaporator feed pump; valve connections through pipes to the distillers, second receivers, and condensers; a brine pump for pumping out the brine. The steam used for evaporating the sea water is called the primary steam and is taken from the auxiliary steam line. The steam from the sea water is called the secondary steam, and when this secondary steam is used as primary steam in another evaporator the evaporators are said to be running multiple effect. At the end of each watch the evaporators are given a bottom blow. The pressure of the primary steam as used varies from 30 to 60 pounds, and that of the secondary steam from 10 to 20 pounds. The primary steam is contained in coils or tubes. The secondary steam is contained in the shell outside the tubes. The water level should be kept regular to prevent priming and the amount of primary steam regulated to the amount of water evaporated. The steam coils are fitted with drains, which should not be opened more than is sufficient to

drain hot water. Zincs are fitted for the same purpose as fitted in boilers. The evaporators are used to keep the fresh-water tanks full, on the feed tanks for make-up feed, and on the reserve feed bottoms for steaming water. The fresh water made must be tested with nitrate of silver each hour for freshness, and the density of the salt water should be over 4 at any time.

4. Coal passers are detailed as messmen and for the care of the firemen's wash room. The yeoman is assigned to the log and storerooms; he is responsible for the books and stores (with the storeroom keepers) of the enigneer's department.

SEC. 6. GENERAL, FIRE, AND COLLISION QUARTERS.

The stations of the men are as nearly as possible made the same as the pieces of machinery to which they are assigned. Several coal passers are assigned to the powder division, and at general quarters each man goes at once to the station assigned him by the powder division officer. The machine shop is utilized as a repair station. For fire and collision quarters the scope of the engineer's force is enlarged to embrace the berth deck between the limits of the fire and engine rooms. General quarters is indicated by the ringing of the general alarm gongs, followed by the bugle call. Fire quarters is indicated by the ringing of the general alarm gongs, together with and followed by the rapid ringing of the ship's bell—one stroke of the bell, fire forward; two strokes, fire aft. Signals vary on different ships. Collision quarters is indicated by the general alarm gongs, one blast of the siren, and the solenoid whistles. The signal to prepare to abandon ship is the provision call on the bugle.

At clear ship for action the following is done by the engineer's force:

1. Men detailed for the powder division go there at once.
2. Fires are made ready for lighting under all boilers.
3. The steam whistle and siren are drained and the steam shut off.
4. All auxiliaries not absolutely necessary are shut down, and all protective deck stop valves to pipes above it are closed.
5. Pressure is put on the fire main.
6. All pumps are put on the drains.
7. Ashes are hoisted.
8. Coal is trimmed down into the lower bunkers (not done for practice).

At collision drill the closing of all water-tight doors and hatches in the engine rooms, boiler rooms, and their dependencies is done by the engineer's force. All available pumps are connected with

the flooded compartments or with the compartments into which the flooded ones drain.

At fire quarters the steam pumps are started when the alarm is sounded, and pressure is put on the fire main. Blowers that lead to the vicinity of the fire must be stopped. When getting under way, coming to anchor, mooring, or unmooring, the men of the engineer force not on watch or especially stationed fall in at their quarters and remain there until pipe down or they are dismissed.

SEC. 7. GENERAL INFORMATION.—INSPECTIONS.—MESSES.

Messes.—The captain of the mess, a petty officer, first class, is responsible for order and proper conduct of all men of the mess; also for the detail of mess striker and temporary relief when necessary. His authority can not be questioned, and he has full authority to give orders and directions to the messmen in regard to cleanliness and the manner of serving food. Complaints concerning food should come through the captain of the mess.

Sleeping on billets.—Men must sleep on their proper authorized billets, so that they can be called at night without trouble. Men who do not sleep on their billets will be responsible for being present when they are required, and the excuse that the messenger did not call them will not be accepted.

Quarters and drills.—Men must be on the alert and come to quarters promptly when the calls are sounded. At regular morning quarters all men that are not on watch and not at work will come. At quarters for coming to anchor and getting under way the engineer's force may not be required to fall in; but all men who wish to remain on the upper decks must fall in and remain there until retreat. At all calls for general drills, general quarters, fire quarters, collision, engineer's force will proceed to their stations unless ordered to the contrary.

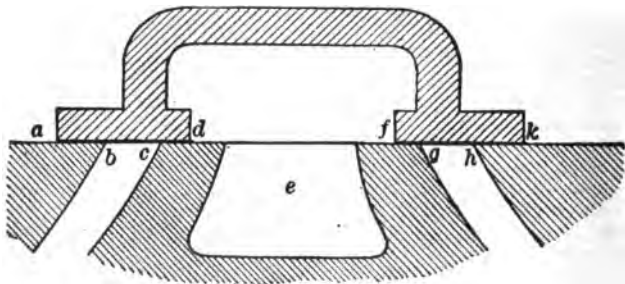
Morning quarters.—The following men of the engineer force should come to quarters in port: Messmen; auxiliary watch that had the 4 to 8 a. m. watch; dynamo, evaporator, and ice-machine men who had the 4 to 8 a. m. watch; steamer crew that has liberty day. Wash room keepers stand by their wash rooms. These men will be mustered and report made. At sea sections not on watch and all men not turning to on their stations are generally required to muster at quarters. On Saturdays and Sundays all men not on watch or excused for work must come to quarters.

PART IV. VALVES.

A valve is a gate by means of which one compartment may be connected with or shut off from another compartment, and for connecting pumps to the pipes leading from compartments. In engineering, valves are found in many forms, but the essential features of all valves are the same. Steam to the main engines is controlled by either an ordinary slide valve or a piston valve.

SECTION 1. THE ORDINARY SLIDE VALVE.

Sketch 1 shows an ordinary slide valve when in mid-position, that is—when the eccentric is at right angles to the line of the



SKETCH 1.

valve stem, this valve is contained within a steam chest filled with live steam admitted by opening the "throttle valve." The straight line *a k* is the cylinder face or valve seat, and contains three openings or ports, of which *b c* and *g h* are the steam ports and *e* is the exhaust port. The amounts that the valve overlaps the steam ports, *a b* and *h k*, are called the steam laps, and the amounts the valve overlaps the exhaust ports are called the exhaust laps, *c d* and *f g*.

The sketch 2 below shows an ordinary slide valve *v*; valve stem *s*; ahead eccentric rod *d*; astern eccentric rod *e*; links, lever, and link block *L, G, F*; eccentrics *B* and *C*; exhaust port *x*; steam ports top and bottom *T, T*; cylinder wall *W*; reversing lever *K*; and reversing lever arm *M*.

When the operating lever is worked the link slides in the block and places either the ahead or astern eccentric rod in line, and through these the valves are worked.

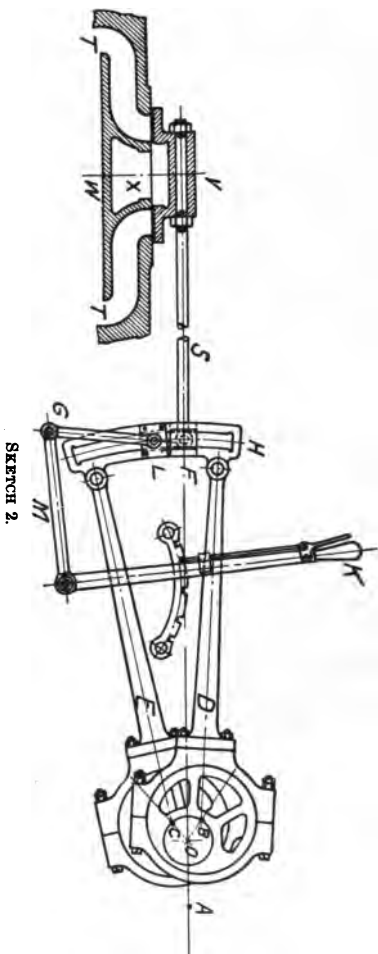
Sketch 3 shows the relative positions of the valve, piston, crank, and eccentric arm for various positions in one stroke of the engine.

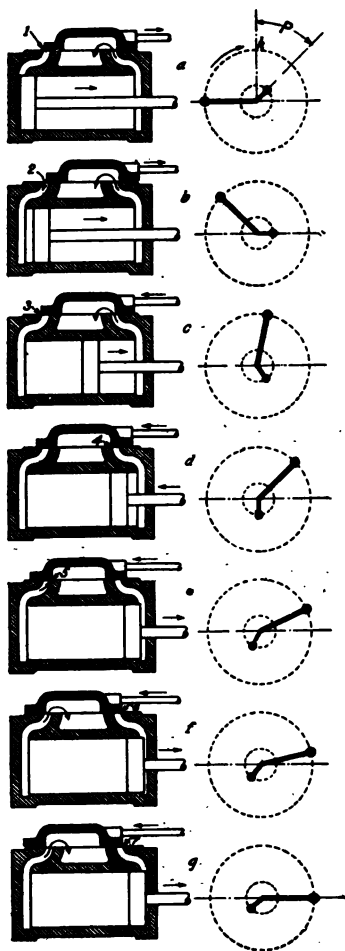
In *a* the crank is on the top center, the piston is at the beginning of the down stroke, the valve is open to steam at the top end, the amount of the opening at 1 being called the lead of the valve. The angle *P* is called the angular advance of the eccentric. It is the size of the angle greater than 90° by which the eccentric is ahead of the crank. If the eccentric were at *h* when the piston was at the beginning of the stroke the angular advance would be zero and there would be no steam lead.

In *b* the valve is at the end of its travel and gives full steam opening at 2 and full exhaust opening at the bottom end.

In *c* the valve has just closed the top end to steam at 3; this is called the point of cut-off.

In *d* the valve has just closed the bottom end to exhaust at 4; this is called





SKETCH 3.

the point of exhaust closure. This occurs before the end of the down stroke of the piston so that the steam remaining at the bottom end of the cylinder may act as a cushion in stopping the piston and changing its direction of motion.

In *c* the valve is just opening the top end to exhaust at 5; this point is called the point of exhaust opening.

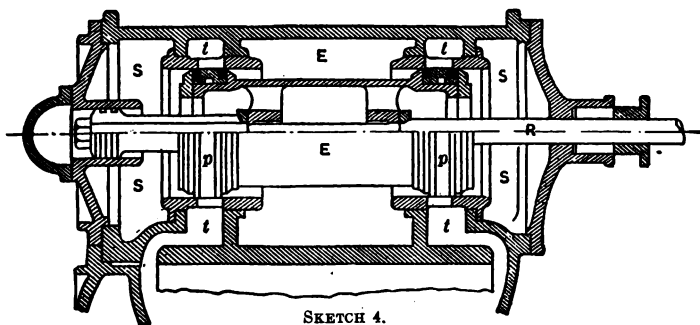
In *f* the valve is just opening the bottom end to steam at 6; this point is called the point of admission.

In *g* the crank is on the bottom center, the piston is at the beginning of the up stroke, and the valve is open to steam at 7; the amount that the valve is open is called the steam lead. The parts are in positions exactly opposite to the positions in *a*.

SEC. 2. THE PISTON SLIDE VALVE.

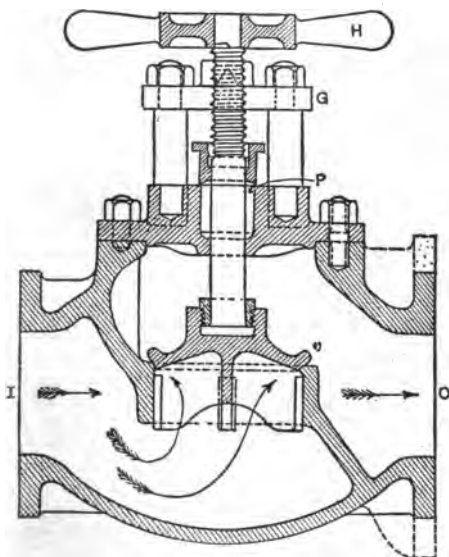
Sketch 4 shows the construction of a piston slide valve. It consists of the two pistons *p p* and the valve rod *R* to which they are both connected. These pistons are fitted with rings as shown. These rings spring out and make the pistons steam-tight, preventing leakage of steam from the steam space *S* to the exhaust space *E*. The

steam ports surround the pistons as shown and are *t t*. The valve rod is made steam-tight by a gland and soft metallic packing.



SEC. 3. GLOBE VALVE.

This valve is shown in sketch 5. The handle *H* is turned to the right in opening the valve, the threaded spindle or valve stem working in the yoke *G* and raising the valve *v*. The valve stem is made tight by the gland and soft packing, shown at *P*. The path of the water or steam through this valve is shown by the arrows. *I* is the inlet, and *O* is the outlet.



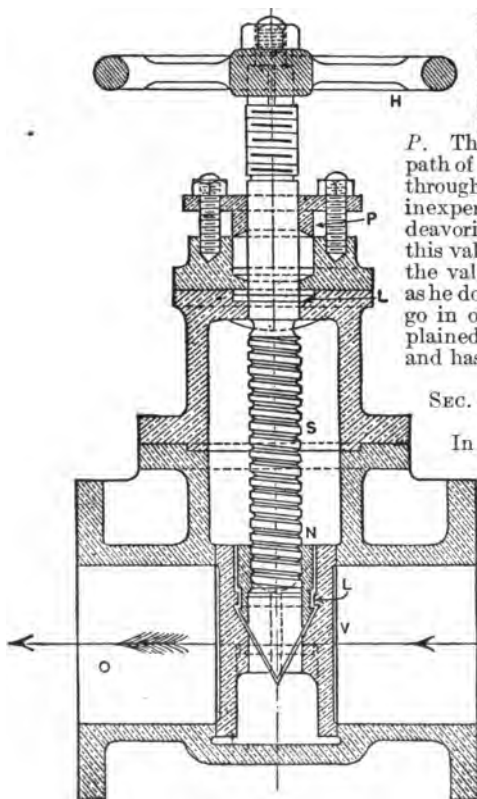
SEC. 4. GATE VALVE.

Sketch 6 shows the construction of a gate

valve. By turning the handle to the right the spindle or valve stem *S* is screwed into the nut *N*, which works up on the valve

stem, raising with it the valve *V*. The valve stem is locked as shown at *L*, and is made steam-tight by a gland and packing

P. The arrows show the path of the water or steam through the valve. An inexperienced man endeavoring to open or close this valve will think that the valve is not working, as he does not see the stem go in or out; but, as explained, the stem is locked and has no travel.

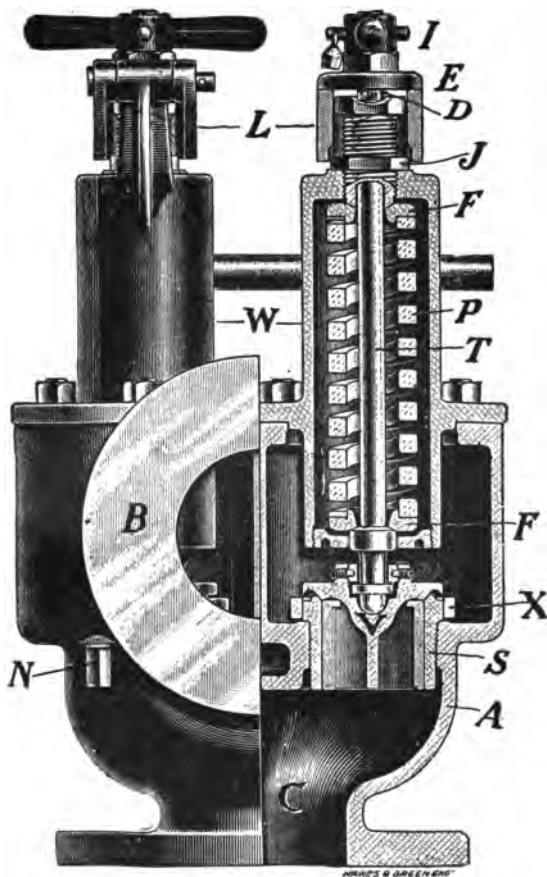


SKETCH 6.

SEC. 5. SAFETY VALVE.

In case the boiler is forming steam faster than the engines will take it, and the pressure becomes greater than the working pressure, in order to relieve this excess pressure a valve called a safety valve is fitted between the boiler and the boiler stop valve directly

on the boiler. Sketch 7 shows a Duplex safety valve, one side being shown in section, called "Duplex" as two valves are fitted in one casing. *X* is the adjusting ring for the valve seat,

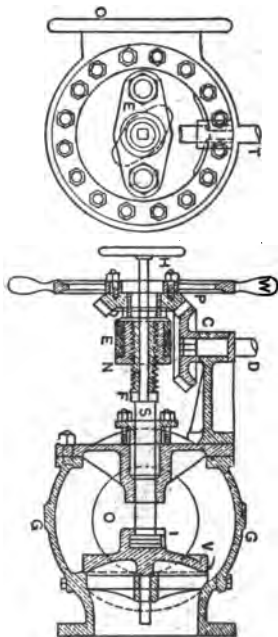


SKETCH 7.

which is fitted in the casing *A*. The spring *P* is of nickel-plated steel and of square section shown. The purpose of this ring is to adjust the amount of reduction in pressure before the valve reseats after lifting. *F* is the compression ring against which the spring rests and is attached to the spindle *T*. As the pressure in the

boiler becomes greater than that the valve *V* is set for, spring *P* will be overcome and the valve will open. To set this valve, the cap *E* is taken off by removing the pin *I*. The lock nut *J* is then slacked off and the adjusting head *D* set to the pressure desired.

SEC. 6. SELF-CLOSING BOILER STOP VALVES.



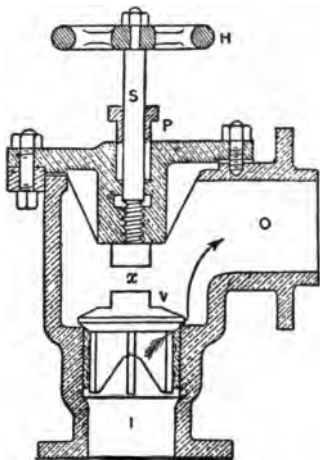
SKETCH 8.

Sketch 8 shows the principle of this valve. The valve *V* is secured to *S*, valve stem, as at *i*; and is made smaller in diameter where it passes through the threaded sleeve *F* to the crossbar *H*. *F* works in a bushing *N* which is bolted to the handwheel *W* and is free to rotate in the steel sleeve *E*. The bevel wheel *P* is screwed on and keyed to the bushing. Geared into this bevel wheel is another bevel wheel *C* connected to the shafting *D*, by means of which the valve is opened or closed from deck. To open this valve the handwheel *W* is turned, rotating the bushing *N*, which raises the threaded sleeve *F* clear of the enlarged part of the stem. The crossbar *H* is now pulled up until the enlarged part of the stem brings against the sleeve

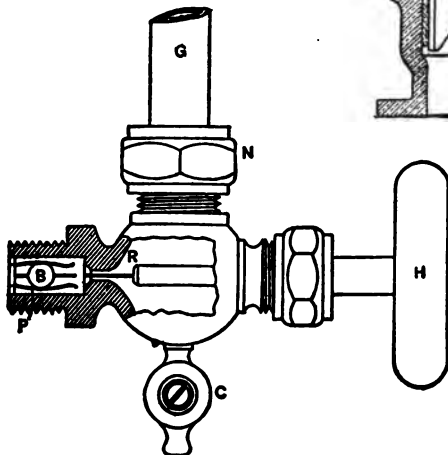
F. In this valve *I* is the inlet and *O* the outlet. The pressure of the steam in the boiler keeps the valve open. If anything happens to the boiler reducing the pressure behind the valve or at *I*, the back pressure from the steam line will strike the top of the valve *V* and close it, shutting the boiler off of the main line.

SEC. 7. BOILER CHECK VALVE.

To regulate the amount of water that is supplied to a boiler, a "feed-check valve," as shown in sketch 9, is fitted to the water drum. The valve itself, *v*, is not connected to the valve stem *S*, but lies on its seat as shown. The valve as drawn is open, and to close the valve the handle *H* is turned, lowering the stem, until it is against the valve itself. As the water from the pump enters the valve it will raise *V* and pass through the outlet *O*. On the return stroke, however, all pressure is removed from the bottom of the valve and if it were attached to the stem it would remain open; then the water in the boiler, which is subject to the pressure



SKETCH 9.



SKETCH 10.

of the steam, would flow back through the valve. But as soon as the pressure from the pump is removed, the valve is seated, or closed, by the pressure of the water and steam in the boiler.

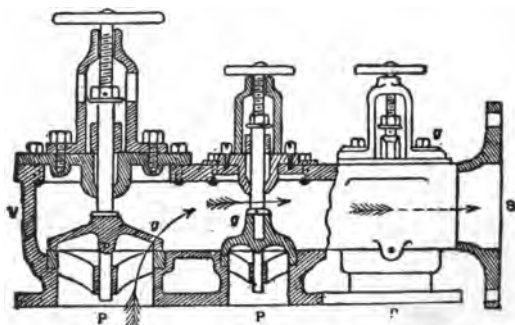
SEC. 8. CROSBY BALL VALVE.

This valve is shown in sketch 10, which also shows the connection of a Scotch water-gauge glass to the boiler. *G* is the glass, packed at each end with a grommet and a gland. *H* is the

handle by means of which the rod *R* is moved in or out. If the glass is broken, the equilibrium between the water in the boiler and that in the glass is destroyed, the boiler pressure being greater, and the ball *B* is forced into its seat, shutting the glass off from the boiler. The broken glass may now be removed and a new glass put in. When the new glass has been put in, the rod *R* is pushed in by the handle and the ball *B* replaced in its pins *P* and the rod *R* drawn out again.

SEC. 9. MANIFOLD OF VALVES.

In order that a pump may be used on more than one compartment or line, a manifold of valves, as shown in sketch 11 is fitted with a suction pipe to the pump. A manifold consists of a valve



SKETCH 11.

chest, fitted with a valve for each pipe that leads into it. When one valve is open and the others closed, the water passes over the other valves, as shown, to the suction pipe at one end of the valve chest, to the pump. In the sketch, *V* is the valve chest; *g g g* are valves; *S* is the suction pipe to the pump; *P P P* are pipes leading from compartments to the valves in the manifold.

PART V.

PIPING.

SECTION 1. PIPING IN GENERAL.

1. Pipes are used on board ship to convey the water and steam from one compartment to another; for instance, the main steam line conveys steam from the boilers to the engines; and the main feed line conveys the water from the feed tanks to the boilers. The auxiliary steam and feed lines may also be used for the above purposes respectively, but they are more frequently used to convey the steam and water to and from the auxiliaries.

2. Piping is usually distinguished by the material of which it is made—(a) copper pipes; (b) brass pipes; (c) cast-iron pipes; (d) steel pipes; (e) lead pipes; (f) steam and water piping. Until the time of the great increase of steam pressures, steam and water piping was generally made of copper, but as the steam pressures became so high, steel piping has taken its place.

3. Piping is also used on board ship to convey the foul and fresh air, and this system of piping is called the ventilating system.

4. Valves are fitted in piping to open or close them from one compartment to another and to connect a line of piping to a pump which pumps water through the pipe or discharges into it.

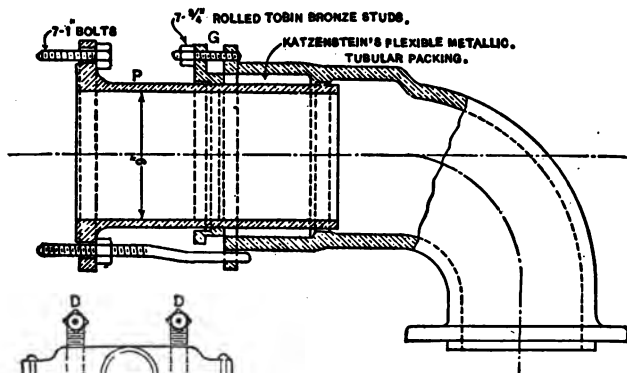
5. Whenever a material heats it is known to expand—i. e., become longer and broader. In order to take up this expansion in lines that convey steam, an expansion or “slip” joint, as shown in sketch 12, is fitted. Use is also made of large bends in pipes, which give to and take up this expansion. An example of this principle is given by the large bends in the steam line connections to the boilers.

6. Pipes for conveying steam are lagged—that is, covered outside by a coating of asbestos and canvas, painted, and this covering prevents loss of heat from radiation. The material used is generally asbestos in forms ready-made to fit the pipes. This is secured to the pipe with wires at the ends; then entirely covered with canvas, which is painted.

SEC. 2. SLIP OR EXPANSION JOINT.

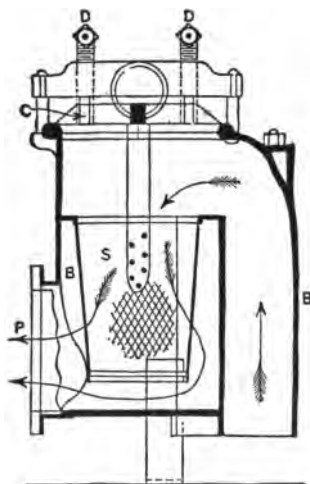
Sketch 12 shows the principles of a slip or expansion joint as fitted in steam lines to take up the unequal expansion due to the heating of the pipe by the steam. The pipe is joined to the joint by the flanges as shown, with 7, 1 inch bolts. The section *P* is free to move in and out of the gland *G*. The gland is packed as shown with Katzenstein's flexible metallic packing set up tight

by the 7, $\frac{3}{4}$ inch rolled Tobin bronze studs. This fitting is made of composition in order to prevent corrosion.



SKETCH 12.

SEC. 3. MACOMB STRAINER.



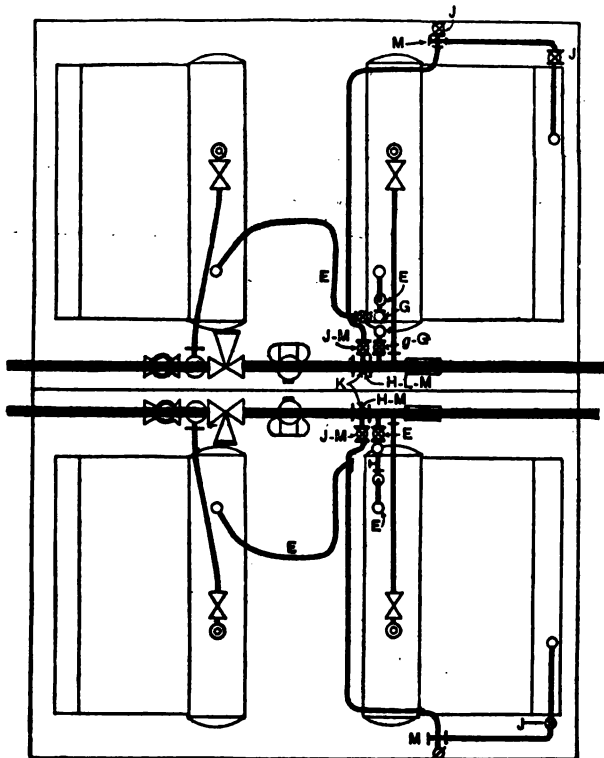
SKETCH 13.

Pipes leading to the bilges, where there is much waste matter and grease that would clog up the pumps and valves, are fitted with a Macomb strainer, as shown in sketch 13. The pipe leading to the pump is joined to the suction box *S* of the strainer at the flange *P*. The pipe leading from the bilge is shown at *B*. *S* is the strainer basket; and to remove it the screws *DD* are slacked off and thrown aside, the holding-down dog is raised, and the cover lifted. The basket is removed, and to clean it steam may be blown through it, or, if

the grease on it is very thick, it may be placed in the ash pan of a steaming boiler and the grease will melt and run off. The arrows in the sketch show the path of the water through the basket and strainer. They should be overhauled once each week and the baskets renewed when necessary.

SEC. 4. MAIN AND AUXILIARY STEAM AND FEED LINES.

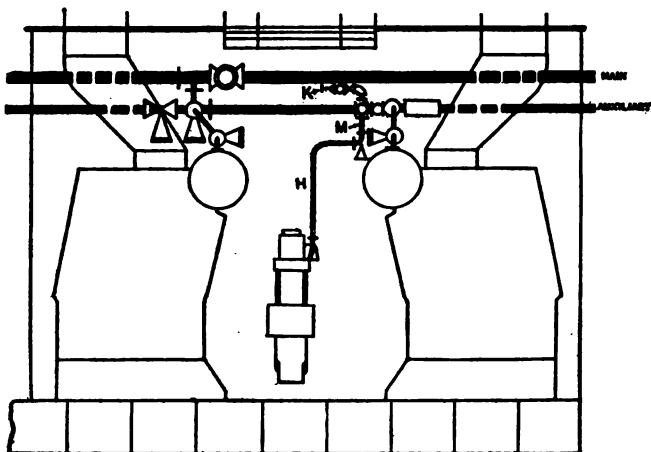
All main and auxiliary steam lines are made of seamless drawn steel and fitted with flanges of steel, which are either stamped or



SKETCH 14.

forged, and the pipe either rolled or welded into the flange and beaded over flush with the face of the flange. The use of steel for steam piping presents the following advantages: Great tensile

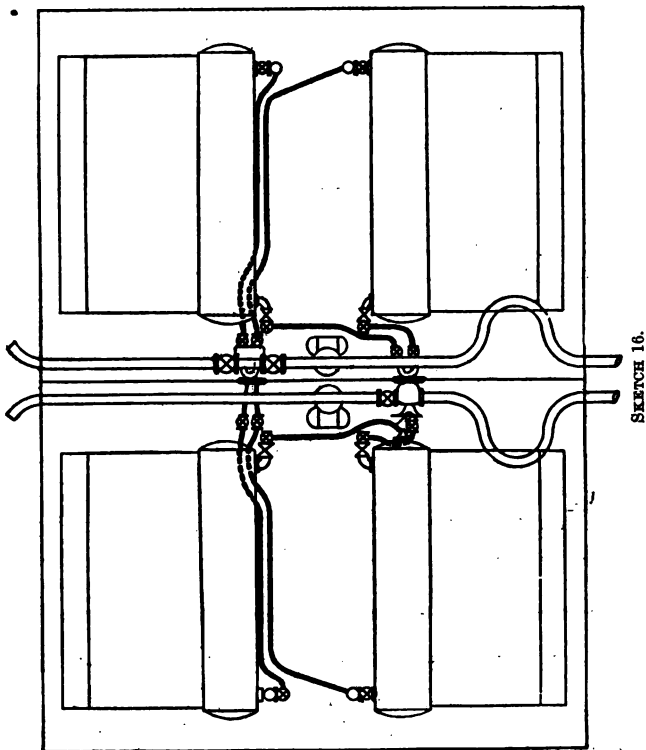
strength; it costs less than copper and lasts longer; it has the disadvantage of weight and the liability to corrode. The arrangement of the main and auxiliary steam lines is shown in sketches 14 and 15 for two double firerooms. Slip joints are fitted in these lines—one in each fireroom compartment—to take up the expansion. The main steam line leads fore and aft through the fireroom compartments and direct to the throttle valve at the main engines. The auxiliary steam line leads from the boilers to all auxiliaries; it is generally placed below the main line in the firerooms. In all



SKETCH 15.

steam-line connections to boilers the safety valves are fitted between the boiler and the self-closing boiler stop valve or directly on the boiler. The line from the boiler is fitted with a by-pass from the auxiliary line used for warming up the main line, and a main feeder valve for connection direct to the main line. There is also a cut-out valve fitted in each compartment, by means of which that compartment may be entirely cut off from the main line. After the main steam has passed the forward engine-room bulkhead, port and starboard, the two sides are cross connected to equalize the pressure. The steam then passes through the separator, where any water in it is thrown out. There is a large

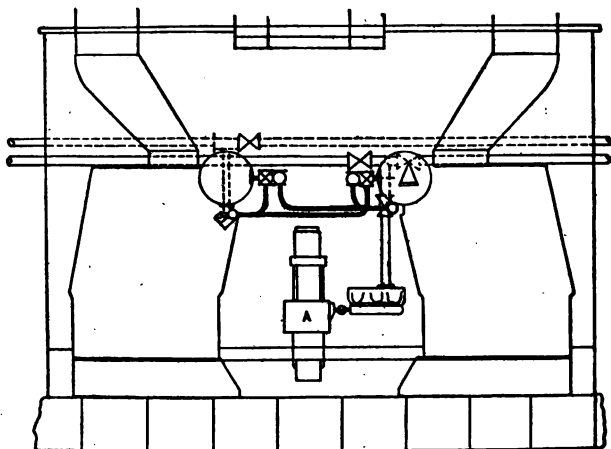
globe valve fitted between this separator and the throttle valve called the main stop, which has to be opened before steam can be had at the engines. All joints between flanges in steam and



exhaust piping are made tight by corrugated copper or fiber gaskets set up by bolts and nuts.

The water in the boilers is converted into steam, which goes through the stop valve and the steam line, and is supplied (the

steam) through a regulating or throttle valve to the steam chest and slide or piston valves to the engines; then it is exhausted from the low-pressure cylinder into the condenser, where it is converted into water. The air pump pumps this water into the feed tank, from which the feed pump puts it back through the feed line and feed check valve into the boilers. An internal pipe is fitted to each boiler in shell boilers to each feed valve, and also in tubular boilers. This pipe directs the incoming water. In shell boilers the main internal feed pipe usually runs above the tubes and points downward in the spaces between the tubes and between the shell and the adjacent nests of tubes on one side, while the auxiliary



SKETCH 17.

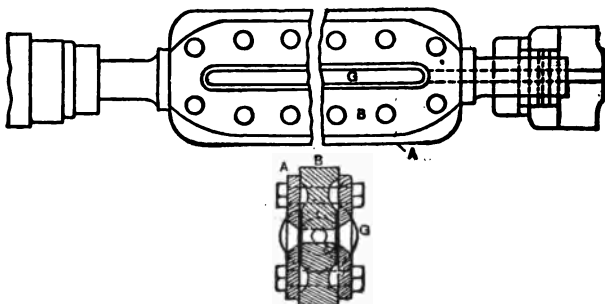
line runs in a similar manner on the other side of the boiler. In tubulous boilers the feed check and stop valves are on the steam drum; and, owing to the height of these drums above the fireroom floor, gears for working them from the floor plates are provided. In order that the amount of water supplied can be regulated for each boiler separately without varying the speed of the feed pump, the latter is fitted with a relief valve which functions if the pressure on the feed line becomes excessive. The leads of the main and auxiliary feed lines for two double firerooms are shown in sketches 16 and 17.

PART VI.

GAUGES.

SECTION 1. THE KLINGER GAUGE GLASS.

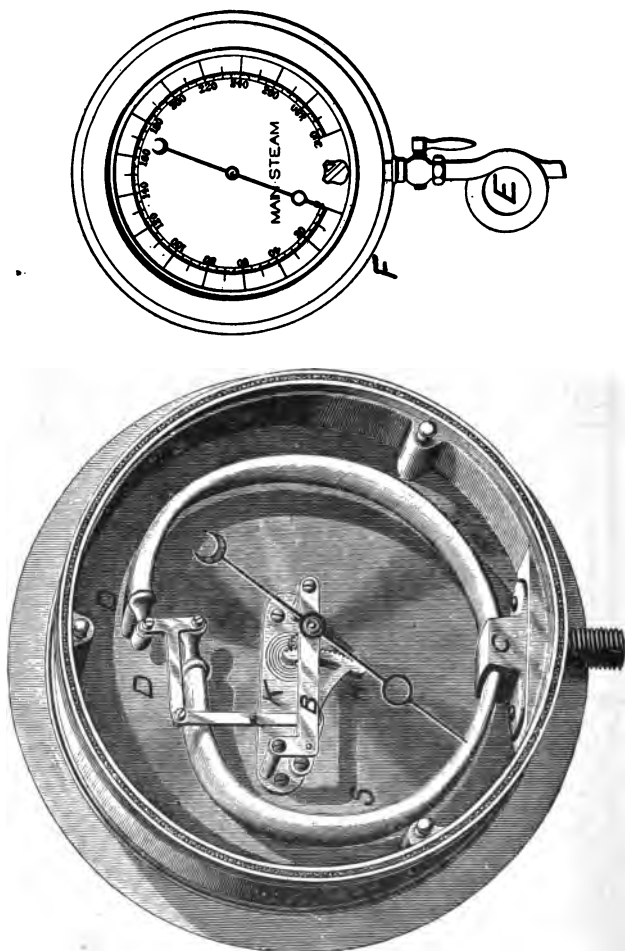
As shown below (sketch 18), this consists of a reflex glass—i. e., glasses scored on one side, which makes the water appear black in the glass, packed in the casing *B* with sheet asbestos, and set up steam-tight by the nuts as shown.



SKETCH 18.

SEC. 2. STEAM PRESSURE GAUGE.

Each boiler has attached to it one or more gauges, by means of which the steam pressure is indicated. Sketch 19 shows one of the types used in the Navy, with the screwed bezel or front, the glass cover and the dial removed. The double Bourdon spring *S* consists of seamless drawn tubing, elliptical in shape, and either plain or corrugated. The upper ends *DD* are closed, and the lower ends open into the hollow socket *C*, which at *E* is connected by a pipe with the steam space of the boiler. The bracket *B*, fixed to the plate *K*, which is fixed to gauge case, supports the bushing for the axis of the pointer and the pin for the slot in the sector *H*. By the system of levers, one end of which is



SKETCH 19.

connected to the ends *DD* of the spring *S* and the other to the tooth sector *H*, any motion of *D* is multiplied and transmitted to a small pinion on the axis of the pointer and engaging with *H*. The spring *S*, being elliptical in shape, with the longest diameter perpendicular to the curvature of the spring, any increase of pressure on the inside will tend to make the diameters of the ellipse equal, and thus cause the tubes to straighten; that is, move the closed ends away from each other. The elasticity of the metal of the springs, if not exceeded, will bring the ends back to their normal position when the pressure is decreased. A hairspring takes up the back lash in the movement when the pressure is going down, and a small pin on the dial stops the pointer at a little above zero. The springs are of such shape and strength that no permanent set is acquired under any pressure shown on the dial. All interior parts are made of noncorrosive materials, and the movement is made as light as possible. The casing is made of brass, sometimes nickel plated. To prevent the ill effect of actual contact of the steam with the springs, all gauges intended for steam must have a siphon fitted to them below *E*, as shown. The siphon is made by bending a complete circular loop in the pipe leading to the boiler (see sketch). In order that it may be effective, the siphon is made sufficiently large to contain enough water to completely fill the springs when under pressure, and so fitted that this water seal will not be drawn out of the siphon when the pressure is off. A small cock, by which the gauge can be shut off, is fitted between the siphon and the gauge. The dial is generally graduated for every 5 pounds by comparison with a mercurial column.

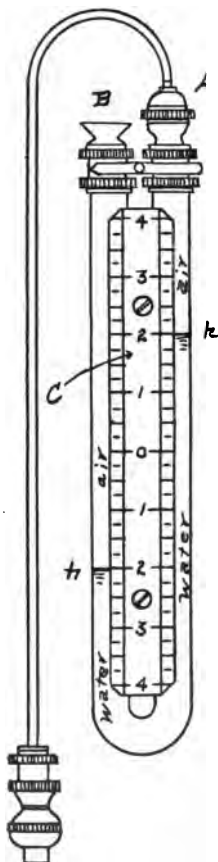
The pointer (hand) is shown reading zero "0" at *F*. This is known as "gauge pressure—gauge zero." It is approximately 14.7 pounds (or atmospheric pressure) above absolute zero. Hence, to obtain absolute pressures, add the barometric or atmospheric pressure to the correct gauge pressure.

To make sure that all gauges on board ship give reliable indications of the steam pressures, they are tested periodically.

SEC. 3. VACUUM GAUGES.

These gauges are used for measuring pressure below that of the atmosphere, generally in inches of mercury, or, as these are commonly called, inches of vacuum. It is in this form that pressures below the zero on the above steam gauges are used and marked on similar gauges, called vacuum gauges. Absolute zero is a perfect vacuum. Hence barometric or atmospheric pressure minus vacuum gauge pressure below gauge zero equals back pressure.

SEC. 4. AIR-PRESSURE GAUGES.



SKETCH 20.

The usual method of measuring the air pressure or the draft is by the difference in level of the water contained in the two legs of a glass U tube, one end of which is open to the atmosphere and the other to the fireroom or duct under air pressure.

Sketch 20 shows the ordinary air pressure gauge without its case. The top of leg *A* is led to the atmosphere when this gauge is used with the closed fireroom system, *B* being open to the firerooms. When the closed ash-pit system is used, *A* is connected to the air duct near the ash pit, *B* being then open to the atmosphere in the fireroom. Scale *C* is graduated in fractions of an inch to represent the difference of level or pressure, the zero mark being at the middle of its height. When there is no pressure, the water level should be at zero. If it is not, water should be added or taken out in order to facilitate the reading of the scale. It will be readily understood that a pressure exerted on the water level in *B*, which will force it down 1 inch, will raise the level in *A* 1 inch, and that the pressure is equal to that of a column of water 2 inches high. This is therefore the air pressure in the fireroom or air duct. The scale may be more conveniently arranged by adopting a sliding scale, graduated from zero up. When a difference in the two legs is shown, the zero of the scale is put opposite the lower level, and the reading of the air pressure taken from the higher level. In this case no attention need be paid to the quantity of water in the U tube.

As the air pressure is frequently given in ounces (per square inch), it will be well to show the relation between inches and ounces.

A cubic foot of fresh water at 62° F. weighs 62.355 pounds; or a column of water 1,728 inches high and having an area of 1 square inch will weigh the same, or, in other words, exert a pressure of 62.355 pounds per square inch. Therefore 1 pound per square inch would be exerted by a column $1,728/62.355=27.712$ inches high, or 1 ounce per square inch by a column of water 1.732 inches high. Taking the reciprocal of this, 1 inch of water column is equal to a pressure of 0.577 ounces per square inch.

Therefore, if there is a difference of 2 inches in the heights of the water levels in the legs of the U tube, we know at once that the air pressure in the fireroom or duct is equal to 2×0.577 , or 1.154 ounces, per square inch. If the difference is 3 inches, the pressure is 3×0.577 , or 1.731 ounces per square inch.

Example: Suppose *B* open to a closed fireroom which is under air pressure from the forced draft blowers; *A* is open to the atmosphere. Suppose the water legs show heights at *h h*. Then we will have $2+2=4$ inches of air pressure, which is equal to $4 \times 0.577=2.308$ ounces per square inch.

PART VII.

PUMPS.

SECTION 1. GENERAL DISCUSSION OF PUMPS.

A pump is a machine by means of which water or any other liquid is transferred from one place to another, and consists of a steam cylinder containing a piston upon which the steam pressure acts, driving a plunger or bucket contained in a water cylinder, fitted with suitable valves admitting water, the suction, and for discharging water, the discharge. Pumps are used on board ship for the following purposes:

1. To supply water to the boilers.
2. To pump out bilges and double-bottom compartments.
3. To supply water as follows:
 - (a) To the fire main.
 - (b) For deck purposes.
 - (c) For flushing out the heads.
 - (d) To the main and auxiliary condensers and to the evaporators.
 - (e) For distilling purposes.

Pumps are either single-acting; double-acting or duplex. A single-acting pump is one that discharges water once every double stroke—i. e., for a vertical single-acting pump, the pump takes water through its suction on the up stroke and discharges it through its discharge on the down stroke. A double-acting pump is one that discharges water on every single stroke. A duplex pump is a combination of two pumps placed side by side, in which the piston rod of one pump actuates the valve movement of the other pump. Liners are frequently fitted in pump cylinders. They protect the cylinder from wear and when worn out can be renewed at small cost.

Pumps are named according to the duties that they perform, and below are given the suctions and discharges of the important pumps in the engineer department.

SEC. 2. MAIN CIRCULATING PUMP.

The duty of this pump is to supply the cooling water to the main condenser. There are two suctions and one discharge: (a) Suction from main injection, discharging through the main condenser overboard; (b) suction from main drain and discharge overboard.

SEC. 3. MAIN AIR PUMP.

This pump maintains the vacuum in the main condenser by removing the air and condensed water, discharging to the feed and filter tank.

A sketch of main condenser with its connections is shown in part 12, "auxiliaries." Sketch 21 (see p. 96), "main air pump," shows this pump with a walking beam "a," connection to the low pressure engine. It may be an independent pump worked by an engine of its own. By the connections *b* and *c* the pump piston *P* carrying the "bucket" with its valves as shown is worked up and down. On the up stroke the foot valves are open and water and air are drawn in to the bottom of the pump through the suction from the main condenser. The bucket valves are closed. The head valves are open and the bucket contents are discharged through the delivery to the feed tank or hot well. On the down stroke the head valves are closed, the foot valves are closed and the bucket valves open, allowing water and air to fill the space above the bucket.

SEC. 4. MAIN FEED PUMP.

Used for feeding the boilers. It has a suction from the feed tanks and discharges to the boilers through the main feed line.

SEC. 5. AUXILIARY FEED PUMP.

Used for feeding the boilers through the auxiliary feed line from the feed tanks, and is available for use in case the main feed pumps fail to feed. This pump may also be used for other purposes and has the following suctions and discharges:

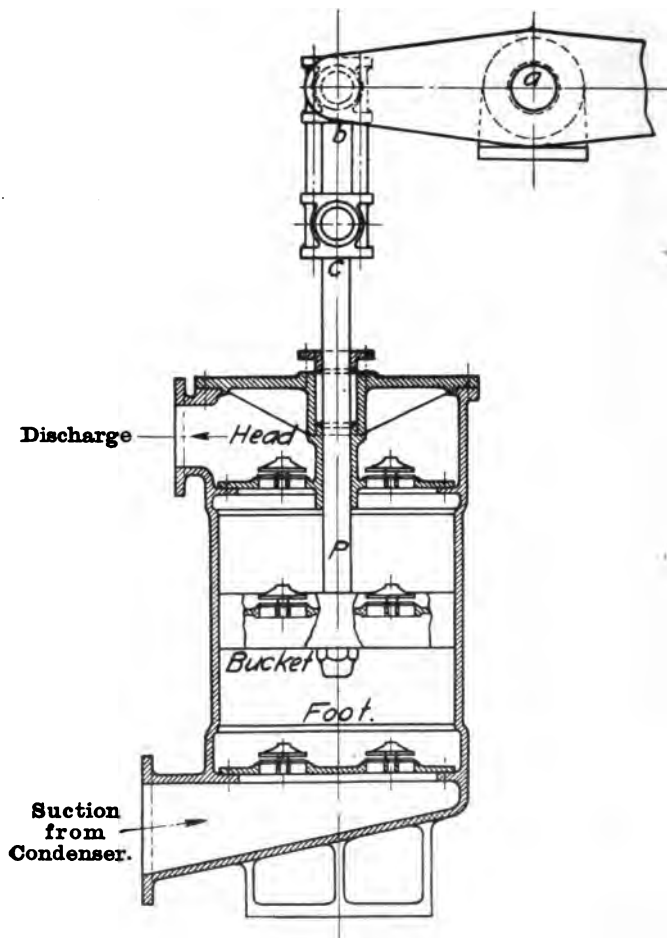
Suctions: (a) Auxiliary feed line; (b) double bottoms or reserve feed tanks; (c) suction from another boiler.

Discharges: (a) To boilers; (b) to reserve tanks or double bottoms; (c) to main feed tanks.

SEC. 6. FIRE AND BILGE PUMP.

Suctions: (a) Shaft alley; (b) sea; (c) crank pit; (d) main drain; (e) engine-room bilge; (f) secondary drain; (g) drain to after system and to drain D-8 to shaft alley manifold; (h) is fitted with cross-connection to the fire and bilge pump in the opposite engine room.

Discharges: (a) Fire main and flushing system; (b) overboard. This pump is also fitted with a valve for cutting out the secondary drain and one for cutting out the after system.



SKETCH 21.

SEC. 7. DISTILLER PUMP.

This pump circulates the cooling water through the distillers. It may also be used to feed the evaporators with sea water, but most ships have a special pump fitted for that purpose, called the evaporator feed pump.

SEC. 8. FRESH-WATER PUMP.

This pump is used to supply fresh water from the fresh-water tanks to the galleys, pantries, and staterooms.

SEC. 9. HOT-WELL PUMP.

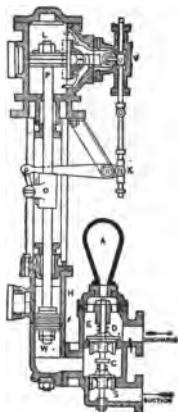
This pump connects direct from the double bottoms to the feed tanks.

Suctions: (a) Main feed tank; (b) air-pump channelways; (c) fresh-water connection to ship's side; (d) reserve feed or double bottom tanks.

Discharges: (a) Main feed tank; (b) main feed pump; (c) double bottom or reserve feed tanks.

SEC. 10. THE SINGLE-ACTING FEED PUMP.

In sketch 22 are shown the principles of a single-acting force pump. As the piston *P* is raised or lowered by the steam pressure within the steam cylinder *L*, the water plunger *W* is raised or lowered in the water cylinder *H*. As the water plunger is raised on the up stroke, the foot or suction valve *C* lifts and water is drawn into the water cylinder through the suction *S*. The delivery valve is kept closed by its spring. On the down stroke the pump forces the water against the upper side of the foot valve and closes it, and against the bottom side of the delivery valve, which opens, and the water is discharged through *E* and *D*.

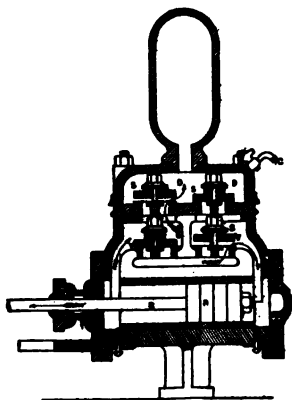


SKETCH 22.

SEC. 11. THE DOUBLE-ACTING PUMP.

In sketch 23 is shown the construction of a double-acting pump. As shown in the sketch the pump is starting on a stroke in the direction of the arrow. The plunger, moving to the left, forces the delivery valve *D* open and discharges the water, the spring *S*

and the force of the water keeping the valve *v* closed. The opposite is taking place in the right-hand section of the pump. The spring *S* closes the delivery valve, and the suction valve *V* lifts, allowing water to enter, which will be discharged as before on the return stroke of the pump.



SKETCH 23.

SEC. 12. HOW TO START A PUMP.

When desiring to start a pump the following procedure must be carried out:

1. See that the exhaust is open.
2. See that the discharge is open.
3. See that the suction is open.

Having made certain of the above, admit steam slowly, keeping the drains open, allowing the pump to warm up gradually. In starting the main feed pumps, the water cylinder may be full of water and the pump water bound. In this case open the relief valves on the water cylinder until the pump runs without pounding. Always start a pump up slowly, allowing plenty of time for it to warm up.

PART VIII.

BOILERS.

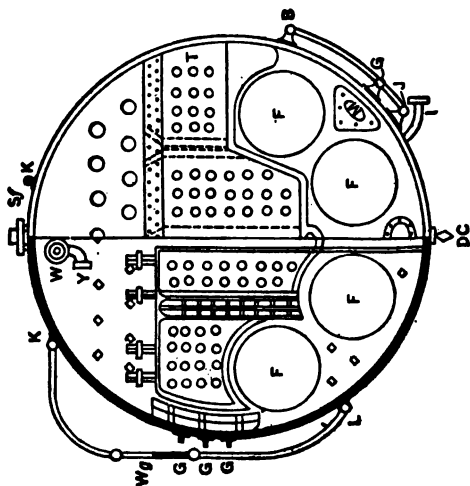
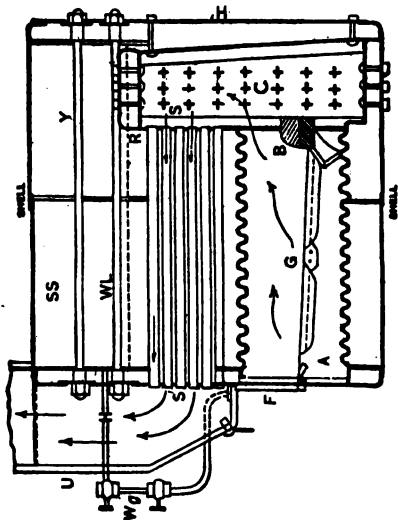
SECTION 1. THE SCOTCH OR CYLINDRICAL BOILER.

1. Sketch 24 (see p. 100) shows a front and side elevation of a single-ended Scotch shell boiler with four furnaces. The cylindrical shell is closed at both ends by the flat heads *H* and *H'*. Inside of the shell are built the combustion chamber *C* and the four furnaces *F*, also the four nests of tubes that are expanded into the front and back tube sheets *S* and *S'*. Above the water level *WL* are the steam spaces *SS* and the through stays *Y*. The coal is burned on the grate bars *G*; and the products of combustion, heat, flame, and smoke, pass as shown by the arrows—first into the combustion chamber *C* and then through the tubes out into the uptake *U* to the smoke pipe. The water gauge is shown at *Wg* and is connected to the top and bottom of the boiler by the valves *K* and *L*. *Sf* is the safety valve fitted between the boiler and the boiler stop valve *W*. The dynamo stop valve is shown at *Y* in the end view. *G G G* are the try cocks, and *I* is the connection to the boiler for the hydrometer.

2. In order to increase the strength of the boiler, stay tubes are fitted among the ordinary tubes. These tubes are shown in sketch 25, and the stay tube is fitted with a cast-iron "ferrule," as shown, on the fire side, to protect it from the heat of the gases of combustion. An ordinary tube is expanded into the tube sheet and beaded over, while a stay tube is threaded and screws into the tube sheet.

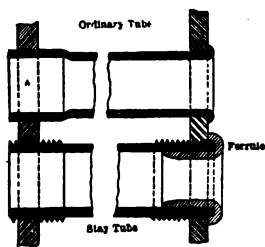
3. To furnish strength to the crown and walls of the combustion chamber, girders, and screw stays are fitted, as shown in sketches 26 and 27.

4. When a tube goes—that is, bursts—instead of having to haul fires and put in a new one, a tube stopper, as shown in sketch 28, is used. *C* is the tube and *A* and *B* the front and back tube sheets. The stopper consists of the iron rod *R* with the nuts *T* and *N*, and the pipe *W*, which is shorter than the rod. There are four washers, one being larger and the other three smaller than the tube itself. Between these washers, rings of rubber or of some soft gasket material are placed, and on the fire side asbestos is used. When a tube is to be plugged, the end *T* is pushed in until the washer

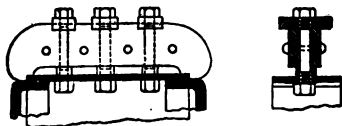


SKETCH 24.

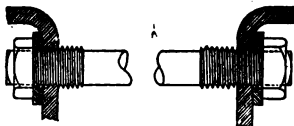
P comes up against the tube. The nut *N* is then set up and the packing compressed until the leak is stopped.



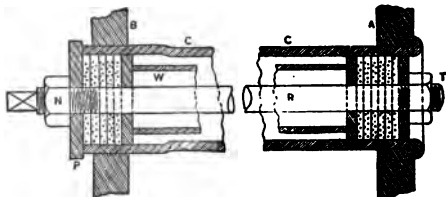
SKETCH 25.



SKETCH 26.



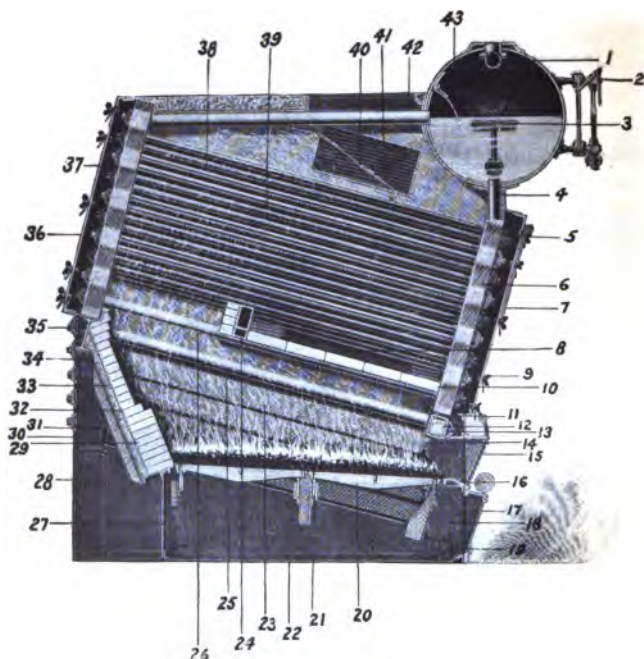
SKETCH 27.



SKETCH 28.

SEC. 2. WATER-TUBE BOILER.

In a water-tube boiler the water, instead of being contained in a cylindrical shell, as in a Scotch boiler, is contained in a drum and the tubes, the products of combustion passing outside the tubes and not through them as in a Scotch boiler. Sketch 29 (see p. 102) shows the arrangement of the parts of a Babcock & Wilcox boiler. Water fills about half the drum and part of the top 4-inch tubes. The water passes from the drum down through the front headers, through the tubes to the back headers, up the back headers, and through the top 4-inch circulating tubes to the drum, where the baffle plate 43 separates the water from the steam and allows the steam to pass up to the dry pipe 1. The course of the products of combustion, shown by wavy lines, is up through first pass, down through second pass, and up through third pass.



SKETCH 29.

The following list shows the correct names for the different parts of the boiler and these names should always be used:

- | | |
|------------------------------|---------------------------------|
| 1. Dry pipe. | 11. Cross box header nipple. |
| 2. Gauge-glass fittings. | 12. End cross box nipple. |
| 3. Scum pan. | 13. Cross box. |
| 4. Drum downtake nipple. | 14. Side box nipple front. |
| 5. Dog. | 15. Furnace door. |
| 6. Front header. | 16. Dead plate. |
| 7. Front tube door. | 17. Ash-pan door. |
| 8. Lower side cleaning door. | 18. Upright front right corner. |
| 9. Butterfly nut. | 19. Front right shoe. |
| 10. Roof. | 20. Grate bar. |

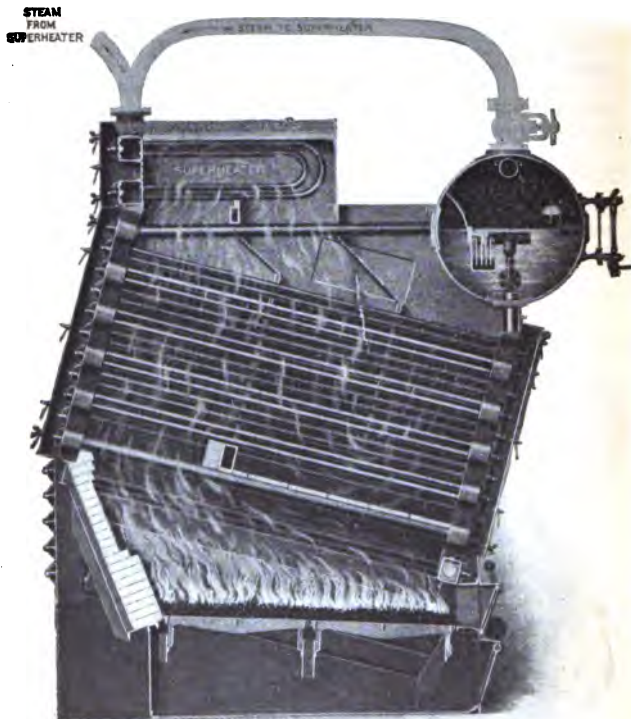
- | | |
|--------------------------------|-------------------------------|
| 21. Bearer bar. | 33. Magnesia blocks. |
| 22. Ash pan. | 34. Bridge wall back plate. |
| 23. Side box. | 35. I beam. |
| 24. Roof block. | 36. Rear tube door. |
| 25. 4-inch side tube. | 37. Rear header. |
| 26. 4-inch generating tube. | 38. Peep hole. |
| 27. Rear closing-in plate. | 39. Flame plate. |
| 28. Rear right shoe. | 40. Baffle plate. |
| 29. Bridge wall. | 41. Upper side cleaning door. |
| 30. Upright rear right corner. | 42. 4-inch circulating tube. |
| 31. Side box nipple rear. | 43. Baffle plate. |
| 32. Asbestos millboard. | |

Sketch 30 shows the construction of the casing of the boiler and the way in which the fire brick, asbestos millboard, and magnesia blocks are placed on the side of the boiler.



SKETCH 30.

Sketch 31 shows the way in which the superheater is installed on a Babcock & Wilcox boiler. The superheater rests on the back headers and 4-inch circulating tubes and the steam is admitted



SKETCH 31.

to the superheater by an outside pipe connecting to the drum. The square parts of the superheater are called superheater boxes. The top superheater box has two division plates in it, dividing its length into three equal parts, and the bottom superheater box has one

division plate in its center, so that steam enters one end of the top superheater box, makes four passes through superheater tubes, and leaves the top superheater box at the other end. In this boiler the baffle plates are arranged so that the superheater is in the first pass of the products of combustion.

Sketch 32 (see p. 106) shows a late type of Yarrow boiler fitted for oil burning. In this boiler the feed water enters the top of each lower drum and is discharged through an internal feed pipe extending the whole length of the drum, and by a baffle shown in the left drum the water is forced to pass up the outer rows of tubes into the steam drum.

Sketch 33 (see p. 107) shows a Normand boiler. The lower sketches show how the tubes are arranged so as to form an inner and outer wall of tubes, so that the products of combustion are forced to pass to the back of the boiler and into the nest of tubes instead of passing up around the drum.

SEC. 3. NOTES ON OIL BURNING.

In order to obtain perfect combustion of the fuel oil it must be reduced to a fine spray and the correct amount of air brought into contact with it. The mixture of air and oil spray burned in a furnace must find sufficient space therein for complete combustion before the gases come into contact with the heating surfaces.

Some oils may be so heavy as to require preliminary heating before they can be pumped, especially so in cold weather.

The following terms apply to oil burning:

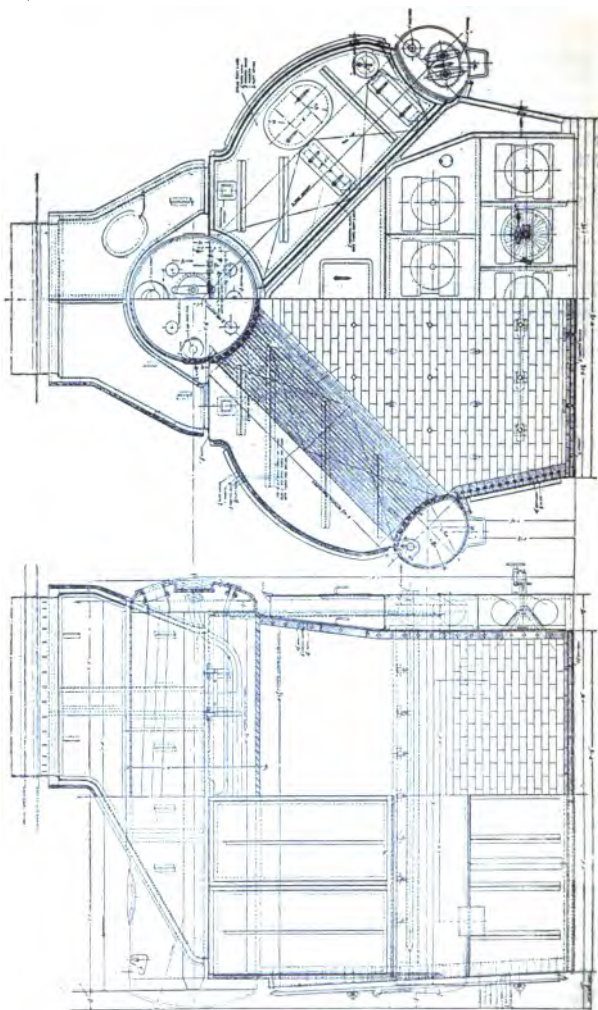
- (a) Drooling, in which the oil oozes out on the steam or air jet.
- (b) Automizing, in which the oil is swept from the orifice by the steam air jet or pressure.
- (c) Chamber, in which the oil mingles with the steam or air in the body of the burner, and the mixture issuing from the nozzle is broken up into minute particles by the expansion of the steam.
- (d) Mechanical spraying, effected by mechanical means without the use of air or other atomizing agents.

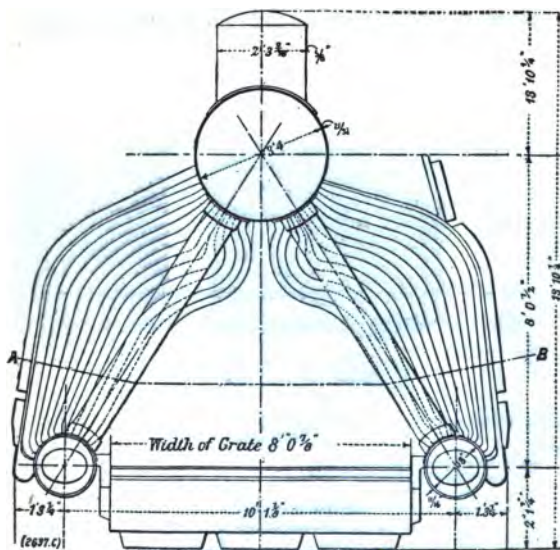
An oil burner should have the following requirements well met: Ease of installation, removal, and construction such as to admit rapid inspection; easy removal of foreign matter; rapid and cheap renewal of parts.

When through with a boiler or when cutting out a burner, especially one having a spindle taper pin valve to close the tip orifice, the entire burner should be removed and cleaned and not closed by screwing home the taper valve, as this is bad practice, resulting in enlargement of the hole in the tip.

The oil to be used must be thoroughly strained.

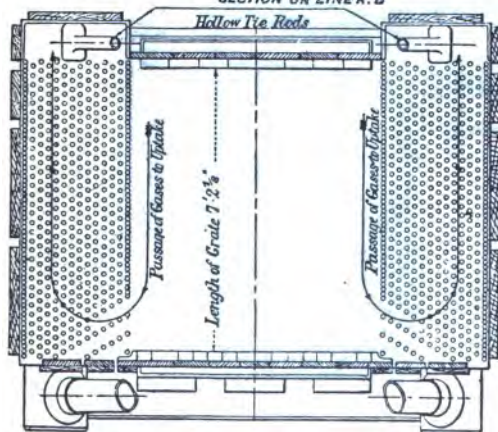
Sketch 34 (see p. 108) shows the arrangement of the burners and air registers as fitted to the Yarrow boiler installation at the fuel-oil testing plant, navy yard, Philadelphia, Pa.



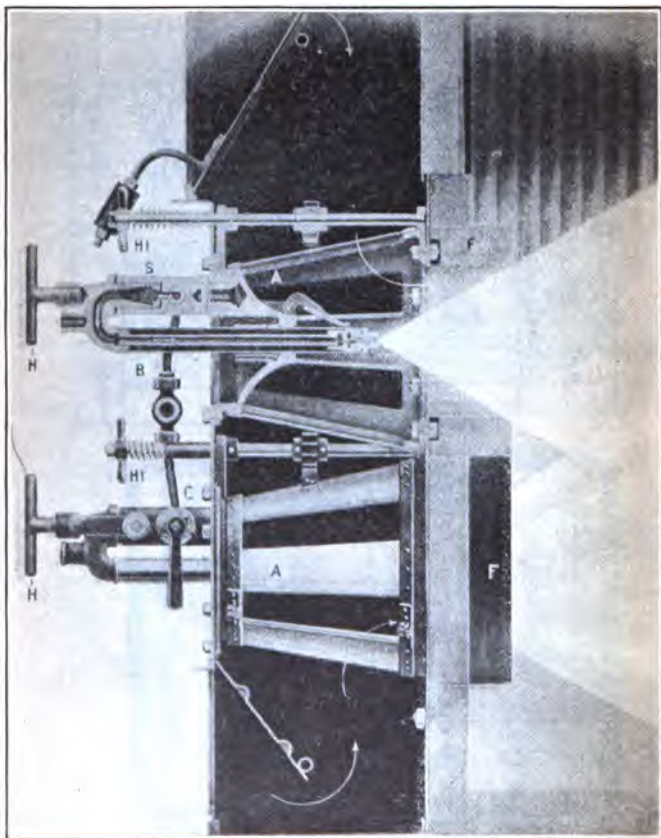


FRONT END OF BOILER WITH FRONT CASING REMOVED

SECTION ON LINE A. B



SKETCH 33.



SKETCH 34.

In the sketch, *A* is the air registers, *B* is the burner, *C* is the oil cock, *F* is the fire-clay cylinder, *H* is the handle for removing the burner, *HI* is the handle for operating the slides for regulating the air supply, *S* is the thimble strainers for straining the oil.

SEC. 4. FUEL-OIL HEATER.

Sketch 35 shows a corrugated, spiral, film design of fuel-oil heater. The oil is supplied to the heater from the tanks by suitable connections with the oil pump.

The oil enters at *EO* and passes up through the film in a spiral path, leaving the heater at *DO*.

The heating element, steam, enters the heater at *ES*, and by means of the branch pipe is carried between the shell and the outer tube and also inside the inner tube, the condensed steam, water, draining off at *DS*, thus giving the desired counter-current, which adds materially to the efficiency of the heater.

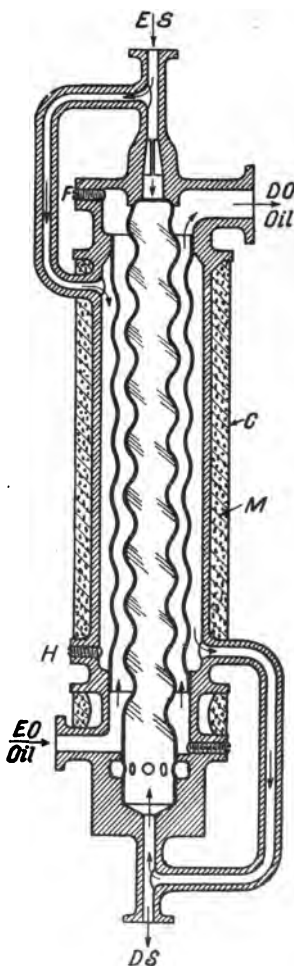
The heater is made of rolled copper tubes and cast-iron (some times bronze) shells.

The heater is suitably "lagged" as shown at *C* and *M*.

The plugs *F* and *F* are removed when it is desired to clean the heater. A steam nozzle inserted at one end and steam at a high pressure blown through the film space will remove nearly all the accumulated oil and sediment. The inner tube may be removed when necessary through the upper end.

H is a plug for rapid draining of the steam side.

The capacity of these heaters is 1 to 4 units, 200 to 9,000 pounds of oil per hour.



SKETCH 35.

PART IX.

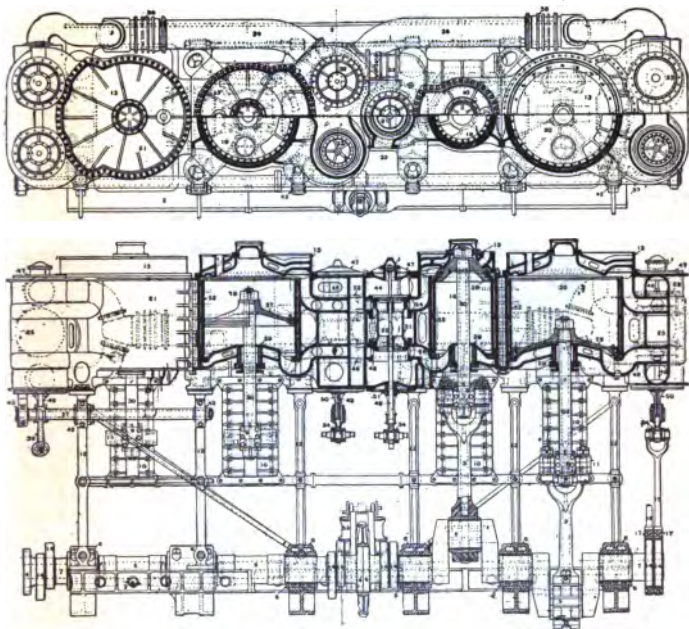
RECIPROCATING ENGINES.

SECTION 1. GENERAL DESCRIPTION OF THE MAIN ENGINES.

In the following description of naval engines the type selected for illustration is that of the armored cruisers *Tennessee* and *Washington*, shown in sketches 36, 37, and 38. The different parts are simply given by name and will be explained individually in later sections of this part No. 9. The engines are of the vertical, inverted cylinder, direct-acting, triple-expansion, four-cylinder type, placed in water-tight compartments, and separated by a middle line bulkhead; i. e., there is a port engine room and a starboard engine room. As the size of the low-pressure cylinder for the required power of a three-cylinder triple-expansion engine would be too large for practical installation on board ship, the power is divided between two low-pressure cylinders whose combined volume (size) is equal to that of the single cylinder, and in order to obtain good balance to make the engine run smoothly and to reduce vibration, a low-pressure cylinder is placed at each end. The order of the cylinders, then, beginning forward, will be forward low-pressure (F. L. P.), high pressure (H. P.), intermediate pressure (I. P.), and the after low pressure (A. L. P.). The forward low-pressure and the high-pressure cranks are placed opposite from each other; i. e., when the H. P. piston is at the beginning of a stroke, the F. L. P. piston is at the end of a stroke, and the cranks are 180° apart. The I. P. and A. L. P. cranks are likewise opposite each other, but this set is placed at right angles to the first set; i. e., the I. P. crank is 90° from the H. P. crank. The sequence of cranks then will be H. P., I. P., F. L. P., and A. L. P.

Referring to the vertical section through the engine center steam on being admitted by the throttle valve enters the middle space of the H. P. valve chest, as the distributing valve within the valve chest is in this case an inside valve; i. e., the exhaust is on the outer sides of the valves, the reverse to the arrangement of the steam and exhaust ports, as shown under the slide valves, Part IV, section 1. This valve is of the cylindrical or piston type, and is the type fitted to the I. P. and H. P. cylinders of the engines, using high-pressure steam. (See Part IV, sec. 2.) The piston valve is connected to the valve stem which passes through a stuffing

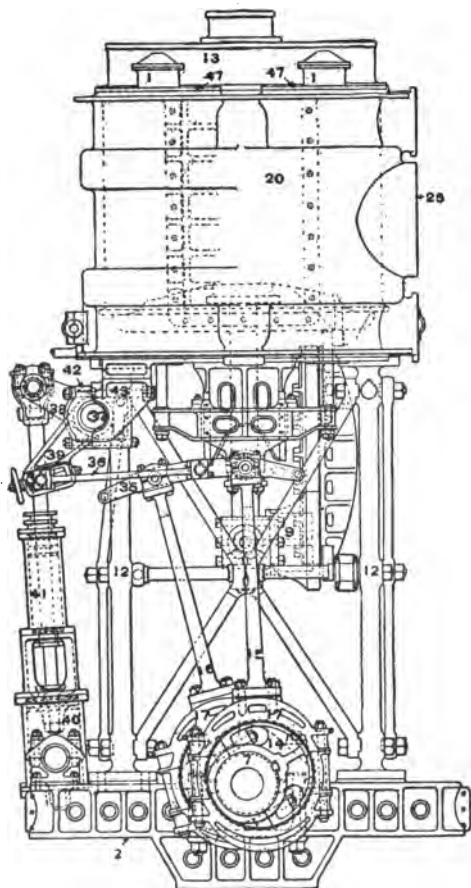
box at its lower end and is connected to the valve gear and eccentrics, from which it receives an up-and-down motion, thus causing the valve to alternately open and close the steam ports giving communication through the passages 54 and 55 to the ends of the cylinder.



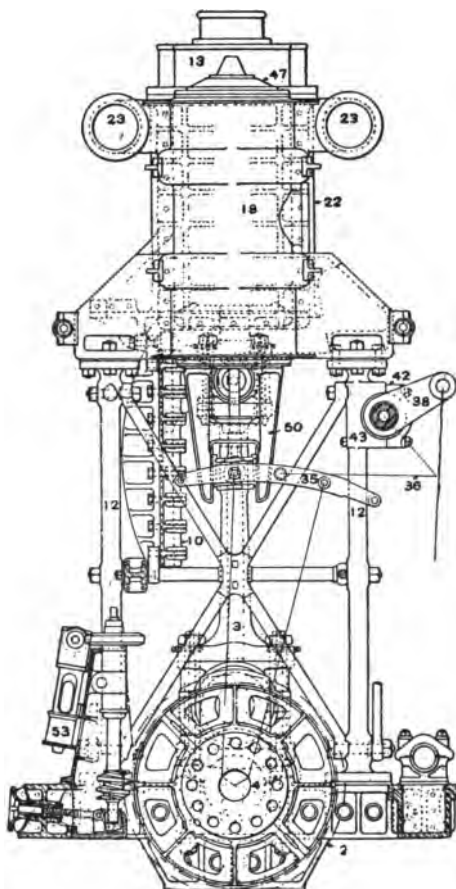
SKETCH 36.

By thus admitting steam alternately to the upper and lower ends of the cylinder the steam piston is driven up and down, this reciprocatory rectilinear motion being converted into circular motion at the crank shaft through the connecting rod and crank.

After the steam has utilized its energy in driving the piston, it is exhausted at the end of the stroke, the valve having moved so as to admit live steam at the opposite end, while the other end is



SKETCH 37.



SKETCH 38.

exhausting through the same passages and ports by which it entered, but passing out by the opposite edges of the valve into the exhaust chamber, which in this case is at the end. This space is connected to the I. P. receiver pipe. By the term receiver is meant all the space between the piston at the end of its stroke and the valve in the succeeding cylinder.

The exhaust steam from the H. P. cylinder passes from the receiver pipe into the valve chest of the I. P. cylinder, where it acts as admission steam for that cylinder. Owing to its expansion in the H. P. cylinder and receiver, the pressure is less and the volume is greater than on admission to the H. P. valve chest.

From the increased size of the I. P. cylinder a larger valve is necessary, which, in this case, is obtained by two piston valves side by side, similar in their parts and acting in the same manner as a single large valve. The valve stems are both connected to a yoke and are driven by the same (one) eccentric.

After the steam has performed work on the I. P. piston it is exhausted into the L. P. receiver pipes. These consist of two pipes leading from the exhaust space of the I. P. valve chest, one section leading forward to the forward L. P. valve chest, and the other leading aft to the after L. P. valve chest, where the steam is distributed to the cylinders in the same manner as before by the aid of two distributing piston valves. From the L. P. cylinders the exhaust steam passes into the exhaust cavity in each valve chest and from there it is carried through the main exhaust pipe to the main condenser. (See Part XII, sec. 1.)

The reciprocating motion of the valve is given by an eccentric secured to the revolving crank shaft and transmitted by means of the valve gear, consisting in this engine of the Stephenson link gear. The valve rod is connected to a block sliding in a curved link whose extremities are connected to the ends of the eccentric rods of two eccentrics on the crank shaft. One eccentric is used for the ahead motion; this rod is straight, while the other which is a bent rod is fixed on the shaft in a condition to give motion astern. Only one eccentric at a time gives motion to the valve, the valve steam being brought into line with the ahead or backing eccentric rod by sliding the link over the link block by means of the reversing gear. The link for each cylinder is connected up to a reversing shaft so that when the links are thrown over to the position desired they all move simultaneously.

The piston works steam tight within the cylinder and is secured to the upper end of the piston rod; and at the lower end of the piston rod connection is made with the crosshead, consisting of a rectangular block sliding upon the crosshead guides or slides.

These guides are secured to the engine frames. Extending out longitudinally on either side of the body of the crosshead are two crosshead pins for the attachment of the forked end of the connecting rod, each branch being provided with a bearing and connections for one of the pins. The lower end of the connecting rod is connected to the crank pin by means of brasses and caps.

The cylinders are supported by the engine frames and consist in this engine of six front and back columns, each athwartship pair of columns being connected together by diagonal braces, and all tied down fore and aft by horizontal and diagonal tie-rods. The tops of the columns are forged, flanged, faced and secured to the cylinder casting, and at the bottom to the bedplate. The bedplate consists of longitudinal and cross girders of cast steel, and is secured to the engine keelsons which are built up with the hull of the ship.

The crank shaft is made in two sections, each section having two cranks and coupling disks, the sections being coupled to each other and secured by means of large coupling bolts and nuts.

The crank shaft is held in a number of main bearings fitted in recesses in the cross girders of the bedplate. These bearings consist of two busses, upper and lower, lined with white metal to reduce the friction and secured by the main bearing bolts. The main journals revolve within these brasses, a journal being the technical name given to that part of the revolving shaft inside the bearing. Two main bearings are usually fitted to each crank, placed as close to the crank arms as possible.

The crank is composed of two crank arms or webs and a crank pin, this latter forming a journal for the crank-pin brasses on the end of the connecting rod. The whole crank is in one piece with the shaft for naval engines, forged solid and afterwards machined to the proper shape and size. The space recessed in the engine frame under the crank is called the crank pit.

A reversing engine is mounted on the bed plate as shown in the elevation of the L. P. cylinder, sketch 37, and is used in moving the reversing shaft, thus throwing the links from one position to another much more quickly and conveniently than by hand power.

A turning (jacking) engine, shown in the sketches, is fitted to each main engine, so that they may be turned without steam on the main pistons. The engines must be moved in port to prevent sticking in any one position, to keep the cylinder surfaces in better condition, for the work of repairs, adjustments, and overhauling.

THE ENGINE BOOK FOR EXHIBITION MEN OF NAVY.

CHAPTER I. THE WATER-STEAM CYCLE.

The purpose of presenting this cycle in a few of the following detail and the main parts of the engine after it leaves the boilers, and the water is made from the water, passing on to the machinery, and then it is again used in the boiler. The main parts are numbered and these

Water is made from the water is fitted to the main steam line and by means of this valve the steam is made from the main steam line.

Water is made from the water is fitted to the main steam line and by means of this valve the steam is made from the main steam line in the engine

Water is made from the water is fitted to the main steam line and by means of this valve the steam is made from the main steam line in the engine

Water is made from the water is fitted to the main steam line and by means of this valve the steam is made from the main steam line in the engine

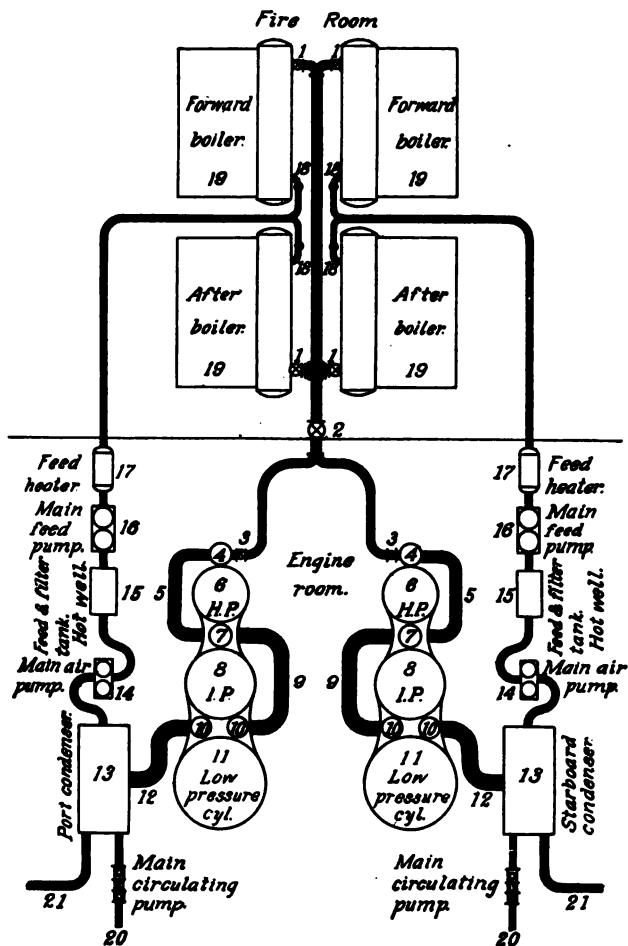
Water is made from the water is fitted to the main steam line and by means of this valve the steam is made from the main steam line in the engine

Water is made from the water is fitted to the main steam line and by means of this valve the steam is made from the main steam line in the engine

Water is made from the water is fitted to the main steam line and by means of this valve the steam is made from the main steam line in the engine

Water is made from the water is fitted to the main steam line and by means of this valve the steam is made from the main steam line in the engine

Water is made from the water is fitted to the main steam line and by means of this valve the steam is made from the main steam line in the engine



SKETCH 39.

SEC. 2. THE WATER-STEAM CIRCUIT.

The explanatory line sketch 39 is for the purpose of presenting to the recruit a general idea, without a lot of confusing detail and elaborate drawing, the path of the steam after it leaves the boilers, in which the steam has been made from the water, passing on through the main engines where it drives the machinery, and then through the condenser, pumps, and tanks, until it is again used in the boilers as water. The main parts are numbered and these numbers represent—

1. **Boiler stop valve.**—One of these valves is fitted to the main steam line leading from each boiler and by means of this valve the boiler is connected to or disconnected from the main steam line.

2. **Bulkhead stop valve.**—This is a large valve fitted in the main steam line, and by opening this valve the steam generated in the boilers is admitted to the piping (main steam line) in the engine room which conveys the live steam to the main engine throttle valve.

3. **Main-engine throttle valve.**—By this valve the amount of steam that is to be used in the main engines is regulated and controlled. If we want to make the engine go faster this valve is opened wider; if we want to stop the engines this valve is closed.

4. **High-pressure valve.**—This is a large piston valve and is shown in detail in Part IV, section 2. By this valve the steam is admitted to the high-pressure cylinder 6, first to the upper (top) end and then to the lower (bottom) end of this cylinder, alternately pushing the piston that is inside the cylinder down and up, and after doing so it is alternately allowed to leave the cylinder, bottom end, then top end, and is said to “exhaust” through the high-pressure valve 4 and into—

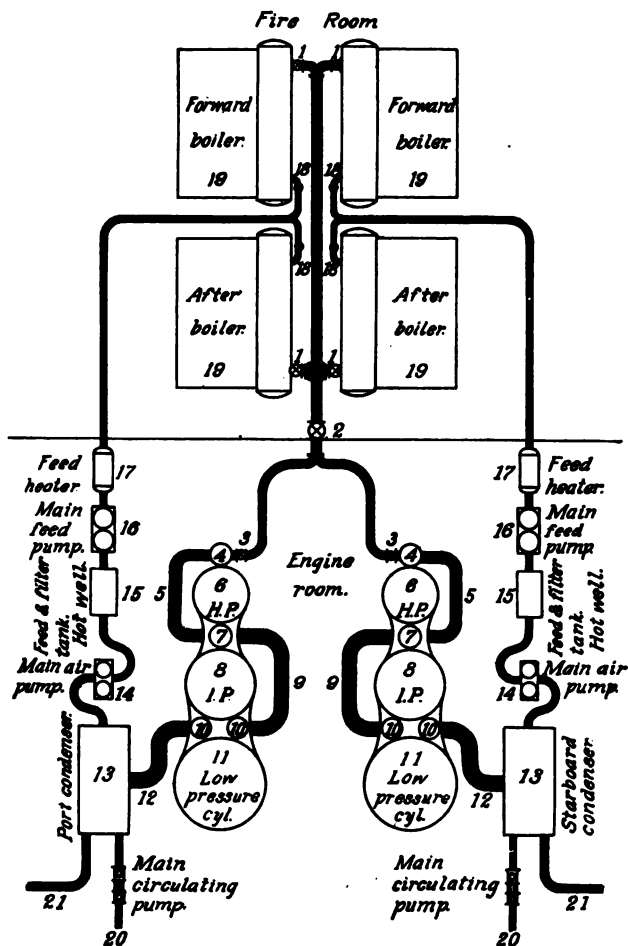
5. **The first receiver.**—A pipe connecting the exhaust (leaving) side of the high-pressure valve with the steam (entering) side of the—

7. **Intermediate pressure valve,** a piston valve similar to the high-pressure piston valve, but larger, and by this valve the steam is admitted through the steam ports into the—

8. **Intermediate pressure cylinder,** where it expands and does work in pushing the I. P. (intermediate pressure) piston up and down, doing work, and is then exhausted through the I. P. valve exhaust ports into the—

9. **Second receiver,** a pipe connecting the exhaust side of the I. P. valve with the steam side of the—

10. **Low-pressure valves.**—As one valve would be very large, two valves are used here, and on small engines a large slide valve



SKETCH 39.

(see Part IV, sec. 1) may be used instead of two piston valves. These valves admit and exhaust steam from the—

11. **Low-pressure cylinders**, where it again does work and leaves by the exhaust ports of the L. P. valves 10 and enters the—

12. **Main exhaust pipe**, which directs the steam to the main condenser. (See Part XII, sec. 1.)

13. **The main condenser**.—(See Part XII, sec. 1.) Here the exhaust steam is changed into water. This condensed steam is taken out of the condenser by the—

14. **Main air pump**.—This pump (see Part VII, sec. 3) is used to remove all air and water out of the condenser and pump it into the hot well of feed and filter tank; at the same time it also maintains a very low pressure, called a "vacuum," in the condenser. This pressure, which is lower than the atmospheric pressure, is also much lower than the pressure in the main exhaust line, and hence permits rapid flow of the exhaust steam away from the engines.

15. **Feed and filter tank—Hot well**.—This is merely a large tank where the water discharged by the main air pump is kept. The water is filtered to clean it of grease and dirt by passing it through loofa sponges in the filter tank. (See Part XII, sec. 7.)

16. **Main boiler feed pump**.—This is a large pump which takes the water from the feed tank and pumps it under high pressure through (see Part VII, sec. 10)—

17. **Feed-water heater**, where the feed water is made hot, (see Part XII, sec. 2), through the main feed line and through—

18. **Main boiler feed check valve**, into the boiler. (See Part IV, sec. 7.)

19. **Boiler**.—In the boiler this water is now heated by the fires in the furnaces and steam is formed for use in the engines.

20. **Main circulating water**.—The sea water for cooling the condensing surfaces of the main condenser is supplied by the main circulating pump 20.

WHAT THE NUMBERS STAND FOR IN SKETCHES 36, 37, AND 38:

- | | |
|--------------------------|------------------------------|
| 1. Balance pistons. | 9. Crossheads. |
| 2. Bedplate. | 10. Crosshead guides. |
| 3. Connecting rod. | 11. Crosshead pins. |
| 4. Couplings. | 12. Columns. |
| 5. Crank pins. | 13. Cylinder covers. |
| 6. Crank-shaft bearings. | 14. Eccentrics. |
| 7. Crank shaft. | 15. Eccentric rod, go-ahead. |
| 8. Crank-shaft brasses. | 16. Eccentric rod, astern. |

- | | |
|---|---|
| 17. Eccentric straps. | 35. Main links. |
| 18. High-pressure cylinder (H. P.). | 36. Suspension links. |
| 19. Intermediate-pressure cylinder (I. P.). | 37. Reversing shaft. |
| 20. Forward low-pressure cylinder (F. L. P.). | 38. Reversing shaft are for reversing engine. |
| 21. After low-pressure cylinder (A. L. P.). | 39. Reversing shaft arm for links. |
| 22. Main steam. | 40. Steam reversing cylinder. |
| 23. High-pressure exhaust or first receiver. | 41. Oil control cylinder. |
| 24. Intermediate-pressure exhaust or second receiver. | 42. Reversing shaft bearings. |
| 25. Low-pressure exhaust. | 43. Reversing shaft brackets. |
| 26. Piston, high-pressure. | 44. Valve chest, H. P. cylinder. |
| 27. Piston, intermediate pressure. | 45. Valve chest, I. P. cylinder. |
| 28. Piston, forward low-pressure. | 46. Valve chest, F. L. P. cylinder. |
| 29. Piston-rod stuffing boxes. | 47. Valve-chest covers. |
| 30. Piston rods. | 48. Valve chest liners. |
| 31. Piston valve, high pressure. | 49. Valve stems. |
| 32. Piston valves, intermediate pressure. | 50. Valve stem guides. |
| 33. Piston valve, forward low-pressure. | 51. Valve-stem stuffing boxes |
| 34. Link blocks. | 52. Cylinder liners. |
| | 53. Turning engine. |
| | 54. High-pressure steam port, top. |
| | 55. High-pressure steam port, bottom. |
| | 56. Expansion joints. |

In connection with the studying of sketches 36, 37, and 38 the section following, "Steam and water circuit," should be followed, tracing the various performances of the steam through the engines. The different points of the stroke for each engine should be noted; i. e., the setting of the cranks. At the coupling 4 are shown the jacking-engine connections, used to turn the engine when it is not in use from one and one-fourth to one and one-half turns each day.

THE SEQUENCE OF EVENTS WHEN THE ENGINE IS OPERATING MAY NOW BE SUMMARIZED AND SHOULD BE MEMORIZED BY THE STUDENT:

- A. Fresh, clean water in the boilers:
 - (a) Water receiving heat from the fires.
 - (b) Water boiling in the boilers.
 - (c) Steam forming from the water in the boilers.
- B. Steam from boiler to engines:
 - (a) Steam leaving boiler through boiler stop valve.

- (b) Steam in main steam line in fireroom.
- (c) Steam passing through the bulkhead stop valve.
- (d) Steam in main steam line in engine room.
- (e) Steam passing through main engine throttle valve to the H. P. valve.
- C. Steam passing through engine to the condenser:
 - (a) H. P. valve chest, H. P. valves, steam ports top and bottom alternately, into H. P. cylinder.
 - (b) Steam in H. P. cylinder, top and bottom alternately, expanding and pushing the H. P. piston up and down and making the shaft and propellers revolve.
 - (c) H. P. valve exhaust ports to first receiver.
 - (d) I. P. valve chest, I. P. valve steam ports, I. P. cylinder, I. P. valve exhaust ports to second receiver.
 - (e) L. P. valve chest, L. P. valve steam ports, L. P. cylinder, L. P. valve exhaust ports to main exhaust to main condenser.
- D. Steam entering condenser to water in boilers:
 - (a) Steam exhausted from L. P. engines entering the main condensers and striking their cooling surfaces; surfaces kept cool by cold sea water circulated through them by the main circulating pump from the main injection valve.
 - (b) Steam condensing into water inside the main condenser.
 - (c) The water (condensed steam) and air, if any, removed from the main condenser and pumped into the feed tank by the main air pump.
 - (d) Water in feed and filter tank.
 - (e) Main feed pump pumping water from main feed tank through—
 - (f) The feed-water heater to—
 - (g) The boiler-feed check valve into—
 - (h) The boiler.

SEC. 3. RECIPROCATING-ENGINE CYLINDERS.

Large marine engine cylinders are composed of the body or shell, consisting of the outer barrel with the lower head, ports, valve chests, and the upper removable cylinder cover, and the cylinder liner or working barrel. Steam cylinders are made of the highest grade of cast iron; the outer barrel or the shell is usually cast with the lower or crank end head, all ports and passages, steam chest and all lugs and feet for attachment to the columns or engine framing. The upper cylinder cover is cast separately and secured by a flange joint and stud bolts to the cylinder shell. The cylinder liner or lining is cast separately and forms the rubbing surface on

which the piston works. To resist the wear of packing rings it is made of very close grained hard cast iron. Sketch 40 shows vertical and transverse sections of the high-pressure and low-pressure

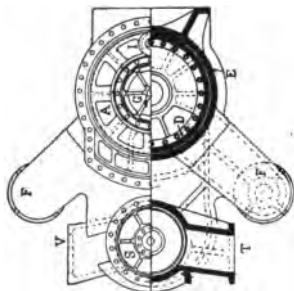
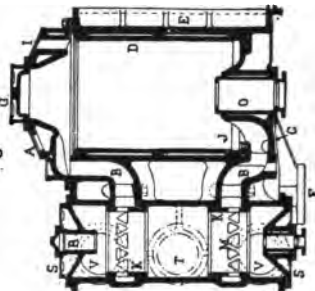


Fig. 2.



Sketch 40.

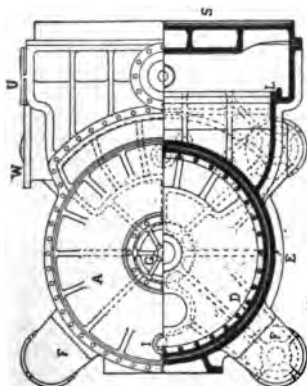
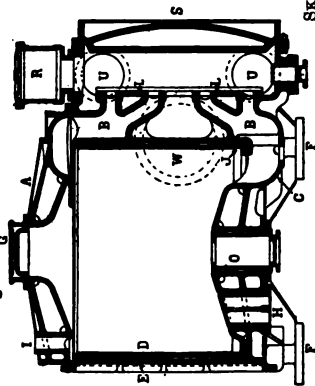


Fig. 1.



cylinders used in triple-expansion engines of naval vessels, together with the valve or steam chests, liners, ports, etc., from which the details can be seen. *A* is the cylinder cover; *B B*, steam ports; *C*, bottom head; *D*, cylinder liner; *E*, cylinder casing; *F F*, brackets

or feet for attachment to the supporting columns; *G*, upper manhole cover; *H*, bottom head manhole cover; *I*, cylinder peepholes; *J*, counterbore in the liner; *K K*, piston valve chest liners; *L L*, false seats in slide valve chamber; *M*, diagonal bridges across steam ports in piston valve chest; *O*, piston rod stuffing boxes; *R*, balance cylinder; *S*, valve chest covers; *T*, steam pipe to H. P. valve chest; *V V*, high-pressure exhaust; *U U*, steam to L. P. valve chest; *W*, low-pressure exhaust. The cylinder or liner is accurately bored to a uniform diameter, except at a short distance from each end, where it is increased, forming the counterbore, so that at the extreme ends of the stroke the piston travels a short distance beyond the main bore, but not enough to permit the piston rings to slip out. By this means the formation of a shoulder at the extremity of the piston stroke, with consequent damage, is avoided.

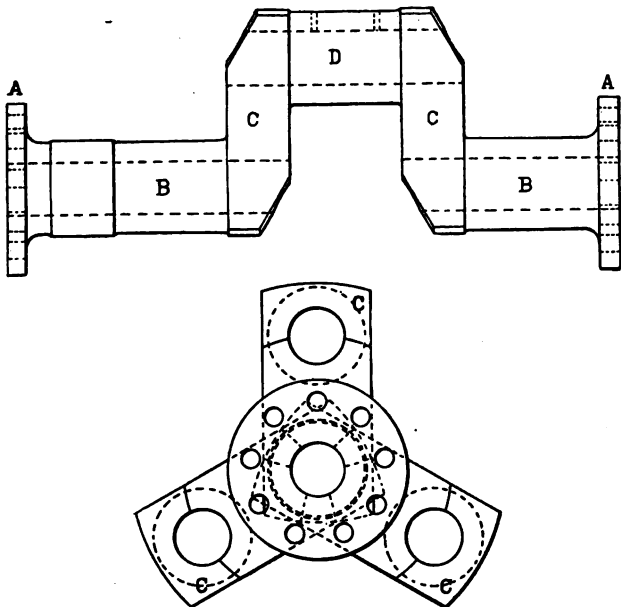
Cylinder lagging and clothing.—All surfaces from which there may be loss of heat from radiation, cylinder walls, valve chests, cylinder heads, valves, piping, etc., are carefully covered with a nonconduction material, such as magnesia or asbestos. This clothing material around the cylinders is kept in place by a walnut lagging or Russia sheet iron, made so as to be readily removable for examination or repair.

SEC. 4. CRANK SHAFT.

For naval purposes the crank shafts are made solid, in sections, and each section has couplings forged on the ends for securing the sections together by the coupling bolts and nuts. The sections are made symmetrical, so that they are interchangeable, and a spare section is sufficient for the replacement of any section. The crank shaft is made of high-grade machinery steel forging and the shaft and crank pins are hollow from end to end, the diameter of the inner hole being about 60 per cent of the outside diameter.

Sketch 41 shows a three-throw crank of a triple expansion engine used in the Navy. *A A* are the coupling disks; *B B*, the crank shaft journals; A journal is that part of a shaft or pin or rotating piece fitting into and rotating in the bearing.

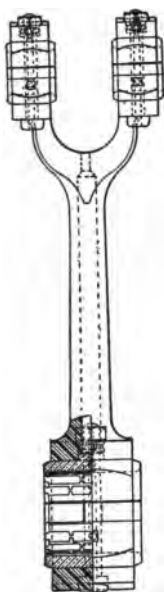
A bearing is that part of a casting or framing supporting the shaft and contains bearing brasses or boxes. When the bearing brasses are made in two parts the line of division should be at right angles to the direction of the maximum thrust. The crank webs are at *C C*, and in naval practice are chamfered. *D D* are the crank pins. The axial holes in the crank pins are used for extra lubrication; one end is closed by a brass plate, the other being fitted with a centrifugal oiling device.



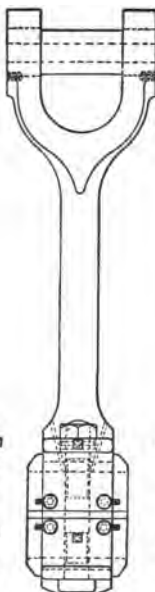
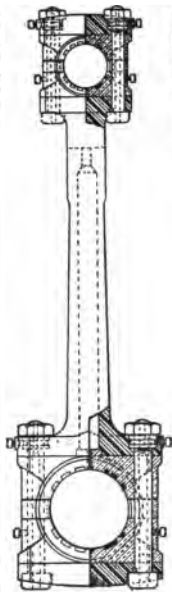
SKETCH 41.

SEC. 5. THE CONNECTING ROD.

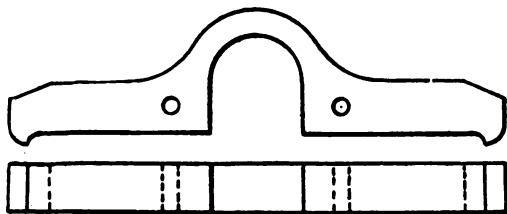
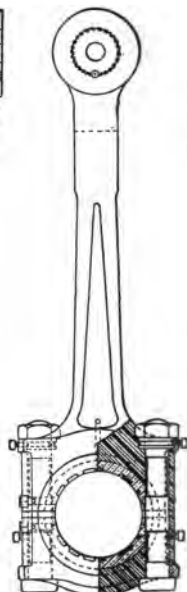
Connecting rods for the Navy are made of high-grade steel machinery forgings and they are hollow, a hole being bored from one end to the other. Sketches 42 and 43 show the types of connecting rods in general use. The type used in the Navy is shown by sketch 42. This rod has a T end at the bottom, with a forked end at the top for embracing the crosshead pins and is fitted with adjustable brasses and connections. For the bearing at the crank end and for each bearing at the crosshead there are two brasses and caps with distance pieces. The parts are connected by means of through-bolts and each bolt is fitted with a collar nut, with a set screw for locking the nut, and one for holding the bolt in place while backing off the nut. The distance pieces, sketch 44, are



SKETCH 42.



SKETCH 43.



SKETCH 44.

fitted between the brasses and held in place by small dowel pins. The brasses are lined with white or antifriction metal.

The length of the connecting rod is measured from the center of the crank pin to the center line of the crosshead pins, and in the naval service is about twice the length of the engine stroke, or, as it is generally expressed—

$$\frac{\text{Length of crank}}{\text{Length of connecting rod}} = \frac{1}{4}$$

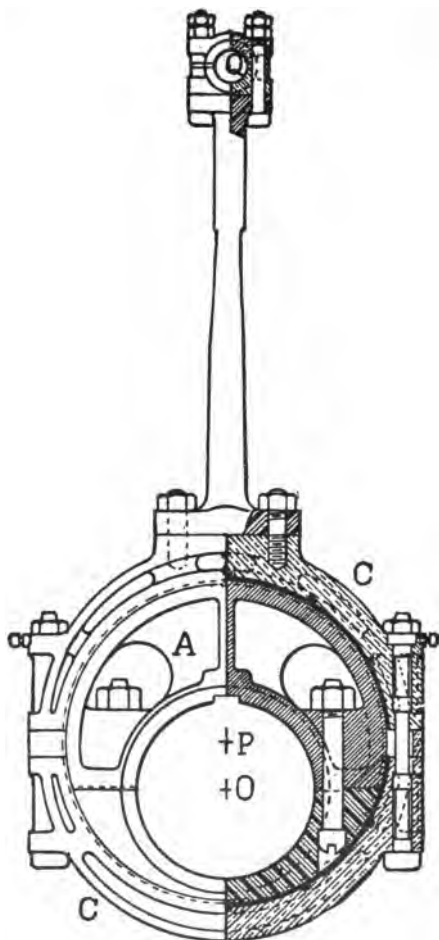
SEC. 6. THE ECCENTRIC ROD AND STRAP.

As stated in Part IV, section 1, the motion of the slide valve to accomplish the desired steam distribution is given by an eccentric and rod connected to the valve stem. The eccentric, sketch 45 (see p. 126), consists of a circular disk of metal, *A*, called the sheave, which is keyed to the crank shaft, revolving with it, but whose center does not coincide with the center of the shaft. The center of the eccentric is at *P*, while the center of the shaft is at *O*. Surrounding the eccentric and moving on it are two semicircular rings, *CC*, forming the eccentric strap, bolted together and attached to the eccentric rod. The other end of the rod is connected by a joint to the valve stem actuating the valve. In marine engines this connection is made through a link. The strap has lips projecting over the side of the sheave, so as not to slip off sideways.

As the crank shaft revolves the eccentric disk or sheave revolves with it and gives to the strap and eccentric rod a reciprocating motion, the same as though it were a crank, *OP*, attached to a connecting rod, *PQ*, the point *Q* being made to move along a straight line, *OQ*, pointing to the shaft center. Practically it is a small throw crank, but having a crank pin enveloping the shaft and of a diameter equal to the diameter of the sheave. The extent of the movement of *Q*, or the distance between its highest and lowest points, is evidently equal to twice the length *OP*. This distance *OP* is called the "eccentricity," eccentric arm, or eccentric radius.

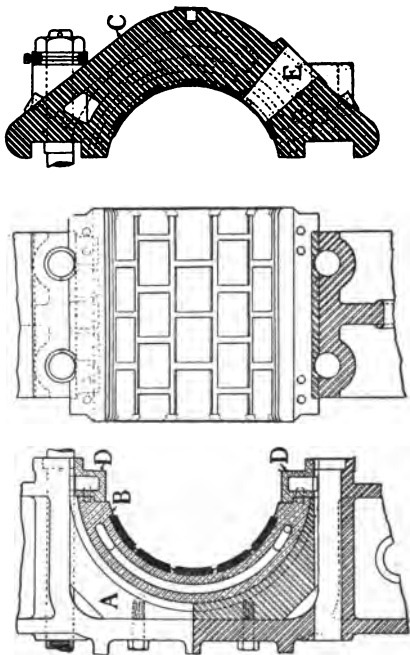
SEC. 7.—MAIN OR CRANK-SHAFT BEARINGS.

The large bearings used for the shafting of marine engines are made so that they may be readily removed for adjustment as wear occurs, and thus prevent distortion of the shaft. Sketch 46 shows one of the crank-shaft bearings of the *Tennessee* class of cruisers. The bottom crank-shaft brasses are made concentric with the shaft



SKETCH 45.

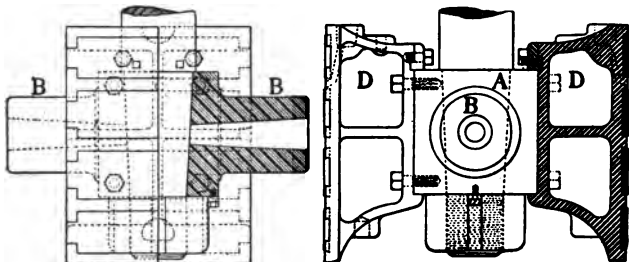
so that they may be revolved and taken out without having to remove the shaft. The bed plate is recessed to receive the bottom brass, which is round at the bottom and can be removed by supporting the shaft and revolving the brass in its cylindrical bed until it comes to the top and so be taken off for adjustment and repair. The bearing has a cap of cast steel, the part coming next to the shaft as well as the bottom brass being lined with white metal scraped to a true fit. Each cap is secured by bolts, provision being made to prevent the nuts from backing off and the bolts from turning. In the sketch each bearing consists of a shoe, *A*, fitting in the bedplate; a bottom brass, *B*; a steel cap, *C*; and distance pieces, *D*. To prevent the round brass from nipping the shaft when heated, it is shouldered against the distance pieces as shown, and these in turn are shouldered against the cap. The cap and bottom brasses are cored to permit circulating water through them. Each cap has an oval handhole at *E*, for the purpose of feeling the journal when underway, and the cap is secured by four collar bolts, the nuts locked to prevent their backing off, and the bolts prevented from turning by set bolts. Tin liners, as usual, are fitted between the distance pieces and caps, to admit adjustment of the brasses after wear.



SKETCH 46.

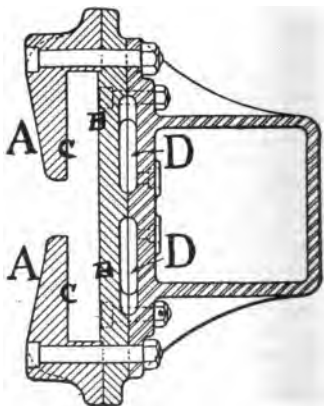
SEC. 8. THE CROSSHEAD.

The crosshead is the head or block at the outer or lower end of the piston rod to which the connecting rod is attached, and guides the



SKETCH 47.

piston rod in a line through the axis of the cylinder in its up-and-down motion. The crosshead travels between two fixed bars parallel to the axis of the cylinder in a straight line, known as the crosshead guides. Sketch 47 shows the open type of crosshead, and consists of a body or block of forged steel, *A*, with the piston rod connected as shown, and on either side longitudinally are the crosshead pins, *B B*, for the attachment of the forked end of the connecting rod by means of adjustable brasses. On the remaining two sides are the removable sliders, *D D*, whose sliding surfaces are faced with white metal fitted in dovetailed recesses. The sliders slide on the guides bolted to the inverted Y columns of the engine framing, containing a guide surface on the back as well as on the front side of the engine. The ahead guide is made hollow to permit the circulation of water to assist in keeping it cool, and the guide surface is usually scored with channels for the distribution of the oil.



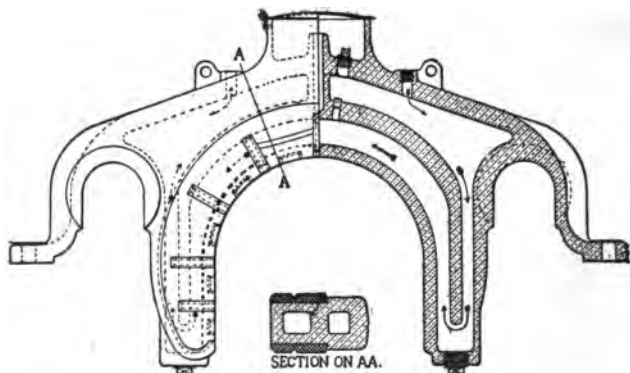
SKETCH 48.

The crosshead pins, like other parts of shafts and pins, with the high-grade material used and careful design, are fitted with axial holes in them, and since the bearings on the journals have an oscillating movement the pins are flattened on each side, the flats stopping a little short of the bearing surface to permit the escape of oil.

Sketch 48, page 128, shows the type of closed crosshead guide bearings in general use. *A A* are the backing guides, *B B* is the ahead face of the slipper, *C C* the backing face, and *D D* is the water back; *C* is made of cast steel in late ships.

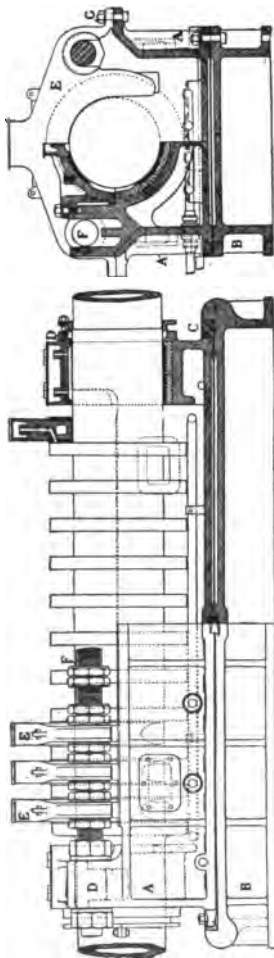
SEC. 9. THRUST BEARINGS.

The shaft immediately abaft the crank shaft is constructed with a number of collars on the journal to bear against corresponding surfaces in the thrust bearing, and thus transmit the thrust of the propeller to the ship, the pressure being exerted on one side of the collars in ahead motion and on the reverse side in



SKETCH 49.

going astern. The bearing is secured firmly to a bearer or seating rigidly connected to the structure of the ship and extending over several frames. The usual form of thrust bearing for all modern vessels, and known as the horseshoe-collar thrust from the shape of the bearing rings, is shown in sketch 50. As applied to the *Louis-*



SKETCH 50.

iana, it consists of 11 collars turned on the shaft with the same number of thrust collars on the bearing. The bearing consists of a pedestal, *A*, bolted to the sole plate, *B*, with holes in the former, so that as wear takes place on the collars the whole block can be adjusted bodily by means of wedges, *C*, bearing against lips on the sole plate. Means of adjustment are necessary, otherwise the shaft will gradually wear forward, throwing the cranks out of line and bringing heavy strains and undue stresses on the engine. The pedestal is made of cast iron, the ends and side walls forming a trough, partially filled with the oil, in which the shaft collars revolve. There is a steady bearing, *D*, at each end, cast in one with the pedestal, and relieves the thrust bearing of the weight of the shaft, so that it has only the duty of taking the thrust of the propeller. Each steady bearing is fitted with a bottom brass and cap both lined with white metal, and at the forward end of the forward and the after end of the after steady bearing there is a divided stuffing box and gland to prevent the escape of oil. The oil trough in the pedestal contains a circulating pipe or coil for cooling water to reduce the temperature of the oil and the bearing.

The thrust bearing collars, *E E*, shaped as shown in the detail sketch 49, are inserted between the shaft collars, and all secured to the two side rods, *F F*, threaded throughout their length, and carried by the pedestal, one on each

side. The holes at the extremities of the horseshoes for these bolts are slotted through, so that each horseshoe may be taken out independently of the others for repairs, and each is fixed in position on the siderods by a shallow nut on each side of the collars, thus securing individual adjustment of each ring. The horseshoes are still further secured or steadied by bolts *G* to keep them from rising. They are made of cast steel, cored for lightness, and faced on each side with white metal and channeled for distributing the oil, and each one provided with an oil box on top, with tubes leading to both faces.

PART X.

STEAM TURBINES.

By LIEUT. O. L. COX, U. S. N.

Turbines are divided into two classes, depending on the manner in which the steam acts upon the blades. When energy is imparted to the moving blades, due to the impact of the moving steam, the turbine is called an "impulse" turbine, and when energy is imparted to the moving blades, due to the "kick back" of steam expanding in the blades, it is called a "reaction" turbine.

There is no pure reaction steam turbine built, because all so-called reaction turbines derive some benefit from impact of the steam and are, therefore, "impulse-reaction" turbines.

A familiar example of an impulse turbine is a windmill or water wheel, and a pure reaction turbine is a "Barber mill," the ordinary revolving lawn sprinkler.

In the former case, rotation is the result of the impact of the air or water on the blades of the wheel, and in the latter the "kick back" of the water leaving the wheel.

In an impulse turbine steam is expanded in a nozzle and the energy in the steam is converted into velocity; this velocity is absorbed by the moving blades and converted into useful work.

In an impulse-reaction turbine the steam expands in both the moving and fixed blades and useful work is obtained, first, by extraction of velocity from the steam on striking the moving blades (impulse), and, second, the "kick back" (reaction) due to the expansion of the steam in the moving blades and leaving at a lower pressure than it entered.

VARIOUS TYPES OF TURBINES USED IN THE UNITED STATES NAVAL SERVICE.

Impulse: De Laval, Curtis, Terry, Kerr, Zoelly, and Sturtevant.

Impulse reaction: Parsons and Westinghouse-Parsons.

A simple form of impulse turbine is the De Laval, consisting of a nozzle or row of nozzles and a wheel with one row of moving blades. In this case the steam is expanded from initial pressure to exhaust pressure, wholly in the nozzle, and steam leaves the

nozzle at a very high velocity (3,000 feet per second more or less, depending on the amount of expansion in the nozzle).

For maximum efficiency the blades should move at approximately one-half the steam speed, which would give a peripheral speed of about $\frac{3000}{2} = 1,500$ feet per second, which with a turbine 3 feet in diameter, would give about 150 revolutions per second.

Such revolutions are too great for commercial use, so that the speed has to be reduced by the introduction of some form of gearing between the turbine and the apparatus it is to drive.

One method of reducing the number of revolutions is by velocity compounding; that is, using more than one row of moving blades on the wheel. Each row of blades extracting approximately twice its own velocity, a two-row wheel would have a speed of approximately one-half that of a single row.

Still another method is by pressure compounding; that is, having two or more wheels in series, with nozzles between and having a smaller drop per set of nozzles, consequently lower steam velocity.

The Rateau is an example of a pressure-compounded turbine. It consists of several wheel stages, each containing a single row of moving buckets.

The Curtis and Zoelly are compounded both for pressure and velocity, as all of the wheel stages have more than one row of moving buckets.

CLEARANCES.

In an impulse turbine all of the expansion of the steam takes place in the nozzles, so that the pressure throughout any one stage is the same; therefore, there is no tendency for the steam to leak over the tips of the blades and the radial clearance can be made as large as desired. The axial clearance should be kept as small as possible, but owing to mechanical reasons in direct-connected marine turbines this can not be made much less than one-eighth inch on each side of the blades at the high-pressure (thrust-bearing) end of the turbine, and increases toward the low-pressure end. Axial clearances at the low-pressure end sometimes are as much as one-half inch.

In the impulse-reaction turbine there is a drop in pressure from each row of blades to the succeeding row, so that the tip clearance must be reduced to a minimum in order to avoid loss in efficiency. The tips of the blades are drawn down to a fine point, so that they will wear down easily in case of rubbing. The axial clearance can be made as large as desired and usually is from one-tenth to one-half inch, as in the impulse type.

In impulse turbines steam is not admitted around the whole periphery of the first few stages, the nozzles occupying a small

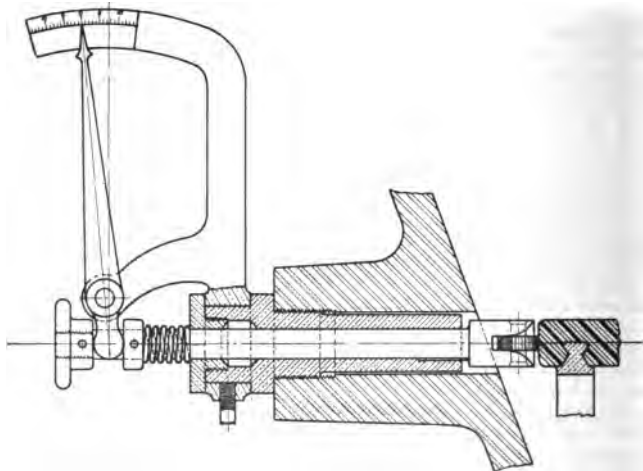
arc of the periphery in the first stage, a greater arc in the second, etc., the nozzles being kept the same height until the nozzles completely fill the circumference, when any increase in nozzle area is obtained by increasing the height of the nozzles.

The nozzles to the first stage are fitted with valves for shutting off, the early designs having a valve for each nozzle. All later designs have one valve for a group of nozzles (2, 3, 4, or 5). By this means it is possible to control the speed, and have the main throttle wide open, simply by opening or closing nozzle valves.

Parsons turbines have full peripheral admission, and any changes in speed are made with the main throttle.

TAKING CLEARANCES.

The axial clearance between the fixed and moving parts of the turbine is obtained by means of a clearance indicator, a simple form of which is shown in sketch 51. It consists of a rod passing



SKETCH 51.

through the casing and has a small steel wheel on the end which is inside the turbine. A true face is turned on the side of some moving part of the turbine, and the wheel runs on this face when the rod is pushed in.

The rod is moved in or out by means of a pointer pivoted near one end. This latter end is rounded and fits between two collars on the rod. The other end moves along a graduated scale which indicates the amount of movement in or out of the rod.

To set the scale, the rotor when hot is pulled forward by means of the thrust-block adjusting bolts until it just touches the stationary parts at some place when jacked over. The rod is pushed in until it strikes the rotor and the position of the pointer noted. The rotor is then shoved aft until it strikes, and position of pointer again noted. The rotor is then put in approximately the mid-position and the zero of the scale adjusted to the pointer. Usually the rotor is so adjusted that there is less clearance on the forward side of the moving blades than on the after. For example, if the total clearance (movement) of the rotor fore and aft is 0.36 inch, the rotor is placed so that about 0.16 inch is the forward clearance and 0.20 the after.

The reading is much simplified if two scales are used, one the reverse of the other. One scale, marked "forward," is adjusted so that the pointer is at "zero" when the rotor is in its extreme forward position; likewise the "aft" scale when the rotor is as far aft as it will go. Then for any position of the pointer the "forward" scale gives the clearance on the forward side of the moving blades and the "aft" scale the clearance on the after side of moving blades, and the distance between the two "zeros" is the total clearance.

BLADE LENGTH.

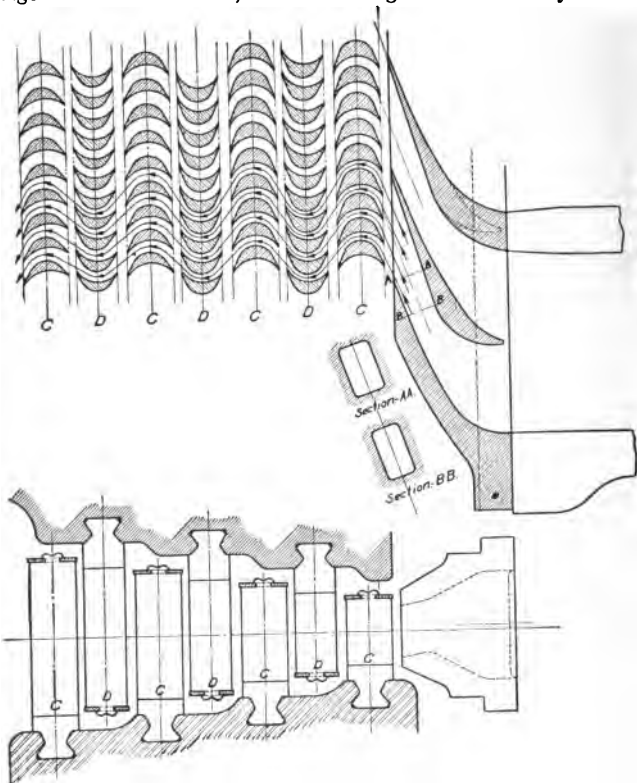
The length of the blades in any turbine depends on the volume of steam passing through and the velocity at which it moves. For Parsons turbines the velocity of the steam is practically constant throughout the turbine (full-speed conditions), so that the increased volume of steam due to expansion is taken care of partly by increasing the length of blades and partly by increasing the diameter of the turbine.

Theoretically each row of blades in a Parsons turbine should be longer than the preceding or else placed on a large diameter. This would make a very costly machine, so that in actual practice a group of several rows (4 to 16) is made identical, the complete group being called an expansion.

The above applies also to the drums of impulse turbines which have one row of moving blades per stage. If a wheel stage contains more than one row of blades, each row must be longer than the preceding one, due to the steam moving with less velocity.

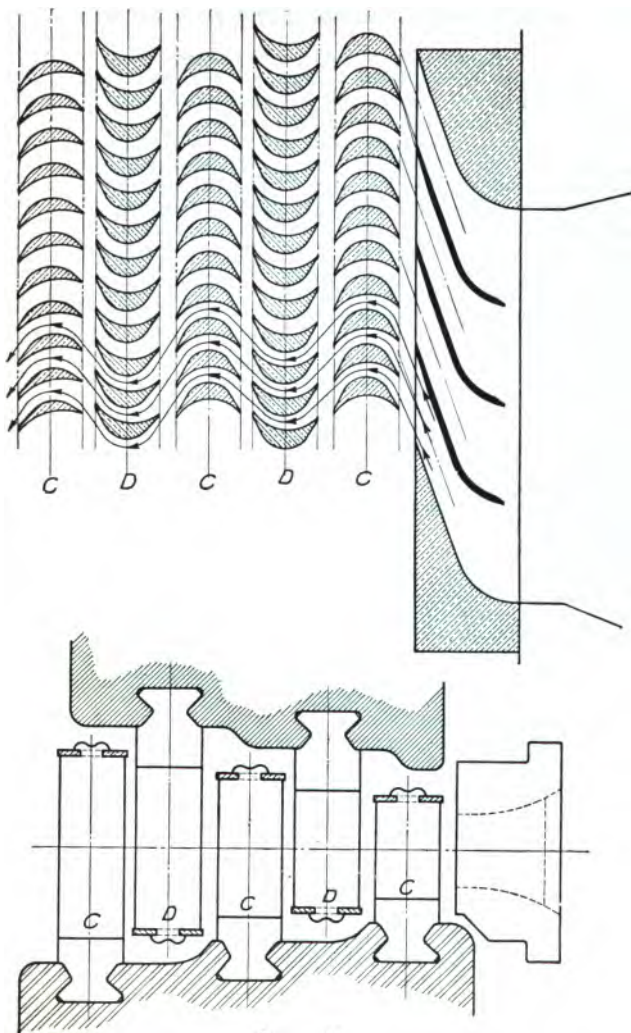
NOZZLES FOR IMPULSE TURBINES.

Sketch 52 shows the arrangement of nozzles and blades for one stage of a Curtis turbine, with 4 moving and 3 stationary rows of



SKETCH 52.

blades, and sketch 53 a stage with 3 moving and 2 stationary rows. The function of the stationary blades is simply to change the direction of the steam, so as to direct it on the succeeding



SKETCH 53.

moving row at the proper angle. The steam from the nozzles passes directly through the blades, so that the band of steam occupies about the same arc of the circumference as the nozzles in use. Therefore, unless the nozzles occupy the whole circumference, it is unnecessary to have the stationary blades all around, and they actually occupy a slightly greater arc of the circumference than the nozzles. The exit angle of the nozzles with respect to the plane of the wheel is made as small as possible in order to give better economy. For mechanical reasons this angle can not be much less than 20° , and is actually 20° in nearly all turbines. The angle is increased at the L. P. end of the turbine in order to give a larger area for the low-pressure (large volume) steam without making the nozzles unduly long.

Sketch 54 shows the drum construction for a Curtis turbine, where each stage consists of a row of nozzles and a row of blades, the nozzles being secured in the casing in the same manner as the moving blades are secured on the drum.

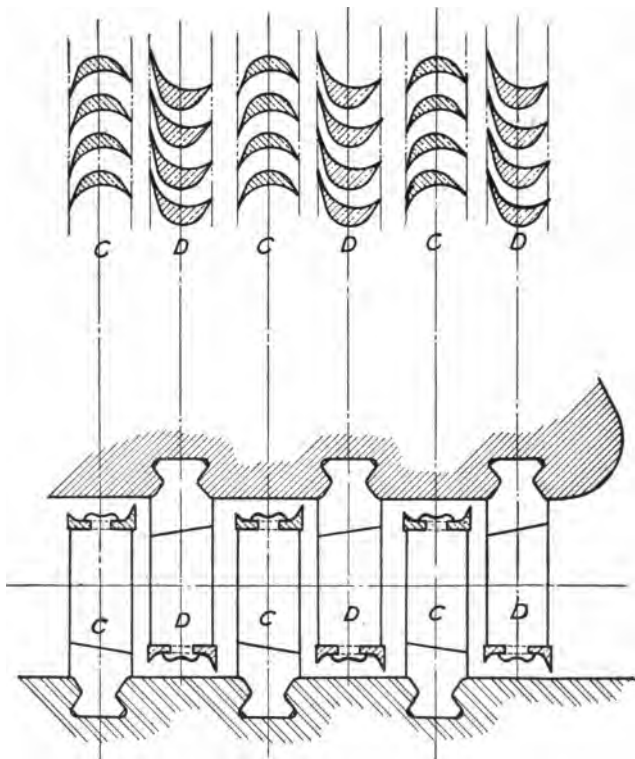
Steam expanding in a nozzle drops to a pressure at the throat (smallest cross section) which is 0.58 of the initial pressure. All pressures being absolute, and if the nozzle is a parallel wall nozzle, as shown in sketch 53 (exit area same as throat area), the mouth pressure is 0.58 of the initial pressure, provided the back pressure is this low or lower. If the back pressure is higher than 0.58 of the initial pressure, then the throat and mouth pressure are the same as the back pressure.

When it is desired to have a mouth pressure lower than 0.58 of the initial pressure, it is necessary to have an expanding nozzle—that is, one whose mouth area is greater than the throat area. The ratio of mouth area to throat area is called the expansion ratio of the nozzle. With a given expansion ratio, the ratio of initial pressure to final pressure should always be the same when the nozzle is working under best conditions.

For example, if in a properly designed nozzle the steam-chest pressure is 250 pounds absolute and first-stage pressure 100 pounds absolute, the pressure ratio $= \frac{100}{250} = 0.4$. Therefore, if, when running at reduced speed, the first stage is 24 pounds absolute, the steam-chest pressure should be $\frac{24}{.4} = 60$ pounds absolute, or 45 pounds gauge, and nozzles and main throttle should be manipulated to give this pressure.

Sketch 52 shows the arrangement of expansion nozzles, and sketch 53 parallel wall nozzles for a Curtis turbine. Expansion

nozzles are seldom used except for first stage where a large pressure drop is desired in order to have a low pressure in the turbine,



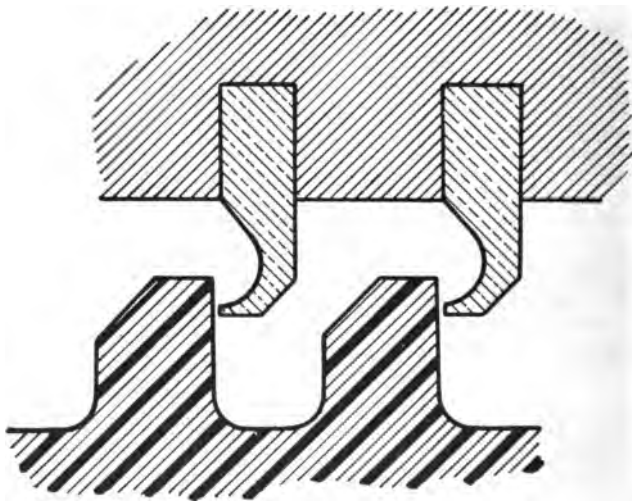
SKETCH 54.

thereby enabling the casing to be made lighter and also to have a smaller difference in temperature from one end of the turbine to the other.

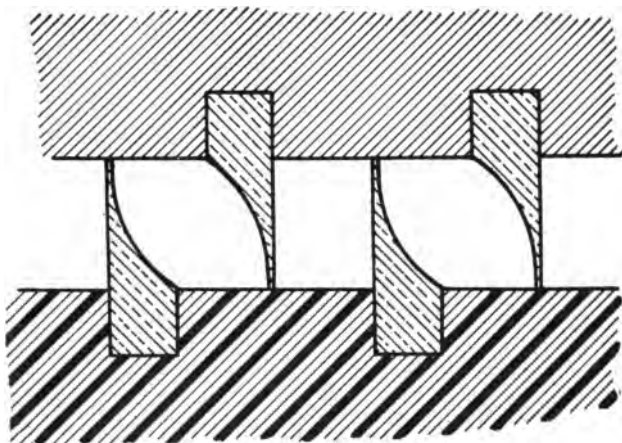
GENERAL DESCRIPTION.

All turbines consist of two parts—the rotor or moving parts, and the stator or stationary parts. The rotor shafts are of forged steel and the drums and wheels of forged steel or cast steel. The casings are made of cast iron or cast steel. Blading, distant pieces, and shrouding are rolled or extruded monel metal or composition. Steel is sometimes used. Binding wires are of copper and nozzle walls are either steel or composition, cast in cast iron or composition.

To prevent the leakage of steam out around the shafts where they enter the casings of Parsons turbines, dummy packing strips are used. These are shown in sketches 55 and 56.

**SKETCH 55.**

Sketch 55 shows the method used for the H. P. (thrust bearing) end of the turbine, and sketch 56 that at the L. P. end.



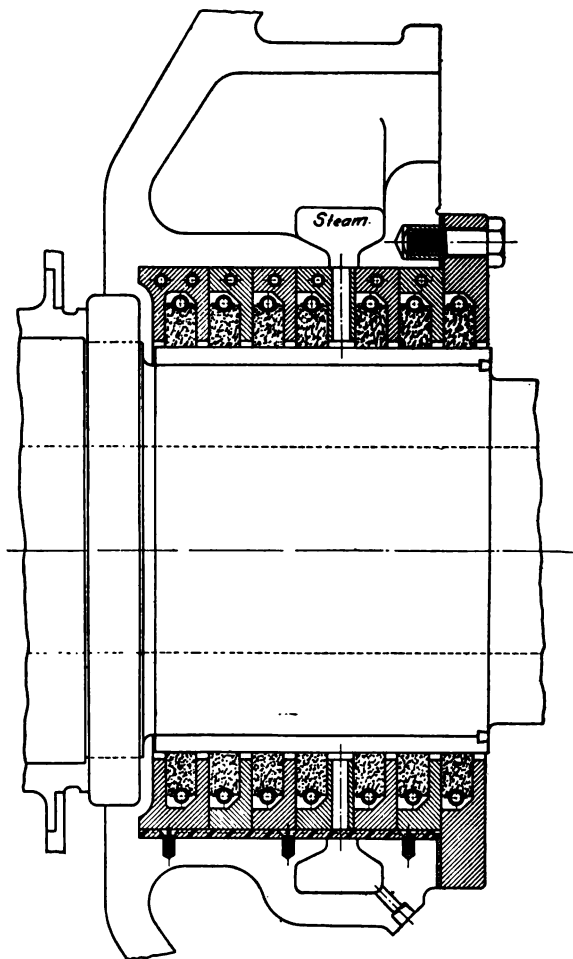
SKETCH 56.

Carbon packing is used on Curtis turbines at both ends of the rotor shaft in place of dummy packing and is shown in sketch 57 (see p. 142). This packing is steam sealed in order to prevent the admission of air at the end of the turbine, which is under vacuum.

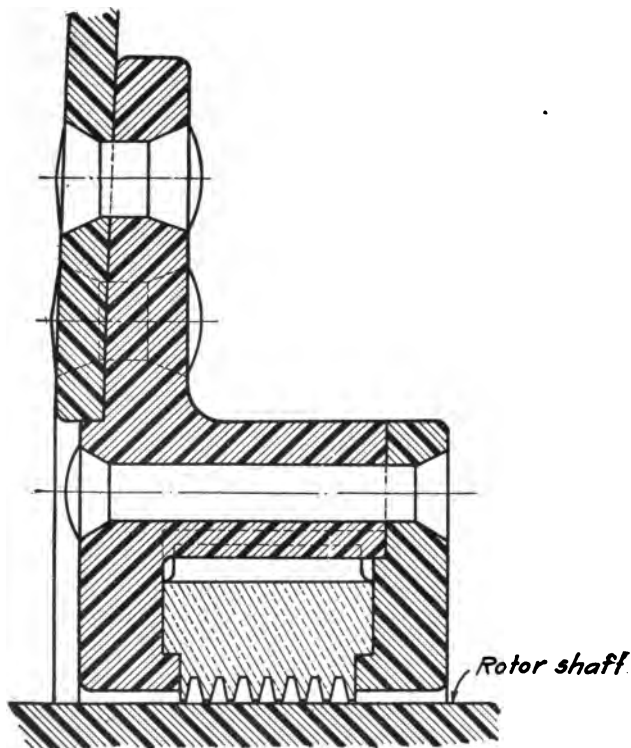
To reduce the leakage of steam from one stage of a Curtis turbine to another, around the shaft, a stuffing box is fitted as shown in sketch 58 (see p. 143). The diaphragm is secured to the stuffing box and is dovetailed into the nozzle holders. The joint between the diaphragm and nozzle holders is shown in sketch 58-A (see p. 144).

Owing to the drop in pressure through each row of blades of an impulse-reaction turbine, there is considerable steam thrust which must be taken care of. In a direct-connected marine turbine this thrust is partially balanced by the propeller thrust and therefore only a small thrust bearing is required. The two thrusts (steam and propeller) balance each other at only one speed; at higher speeds than this the steam thrust is greater than the propeller thrust and at lower speeds the propeller thrust is the greater. Turbines are designed so that at full power the steam thrust is about 20 per cent to 30 per cent greater than the propeller thrust.

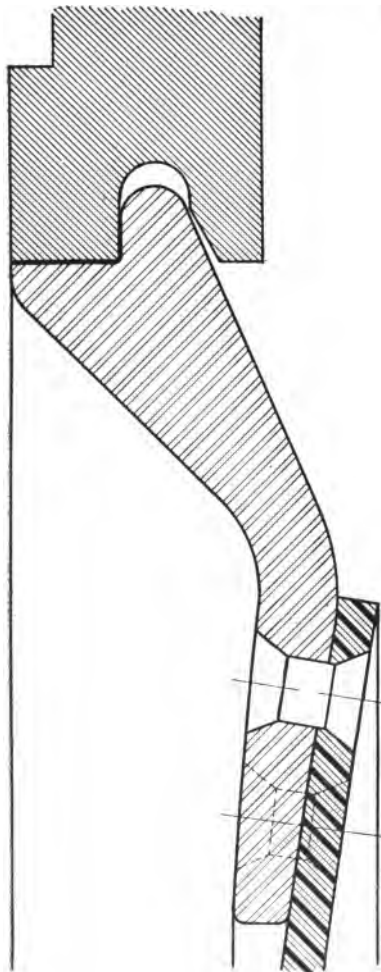
As impulse turbines have very little steam thrust, owing to the pressure being practically the same on each side of



SKETCH 57.



SKETCH 58.

**SKETCH 58A.**

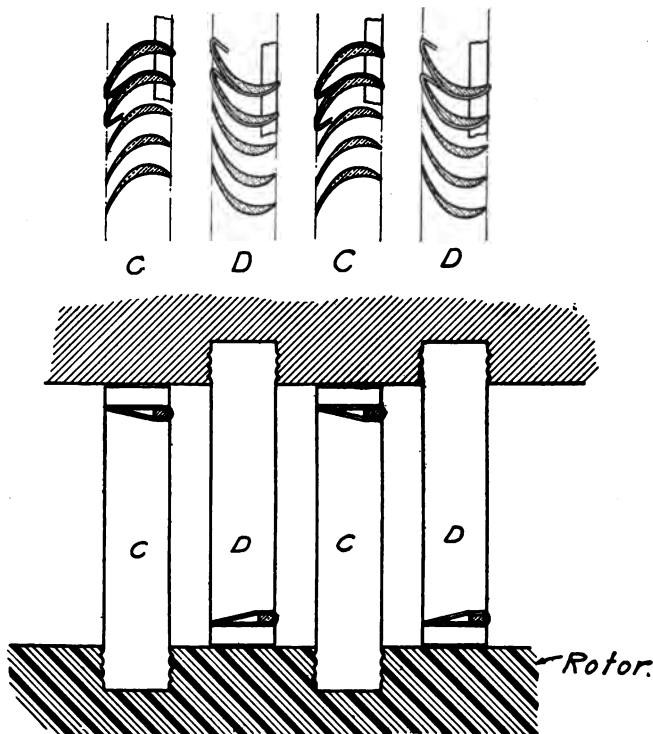
the moving blade, some means has to be adopted to balance the propeller thrust in direct-connected turbines. This is done by using the drum construction. The steam pressure on the drum-head (less exhaust pressure on other head) balancing the propeller thrust and the drum head is so placed that at full power the pressure on it overbalances the propeller thrust about 30 per cent.

If impulse-reaction turbines are used for other than direct-connected units, some means must be taken to balance the steam thrust. This is accomplished by having a "dummy piston" on the shaft, one for each expansion, and a steam connection leading to it from the expansion it is to balance, the exhaust leading to a lower expansion of the turbine. The dummy piston has the same labyrinth packing as shown in sketch 55, the net area of the piston being such as to exactly balance the steam thrust.

In the Westinghouse double-flow turbine steam enters in the middle of the turbine, half flowing in one direction and half in the other; consequently the two steam thrusts balance each other.

SECURING BLADING.

All blading is now secured by dovetailing the root of the blade and cutting a corresponding groove in the drum or casing, packing



SKETCH 59.

(distance) pieces of the same root section are inserted between the roots of the blades to give proper spacing and then lightly calked. After the blading is in place the shrouding or binding strips are put on, shrouding is riveted on, and binding strip soldered,

shrouding being generally used for Curtis turbines, and binding strip for Parsons.

Sketch 59 shows Parsons blading with binding strips.

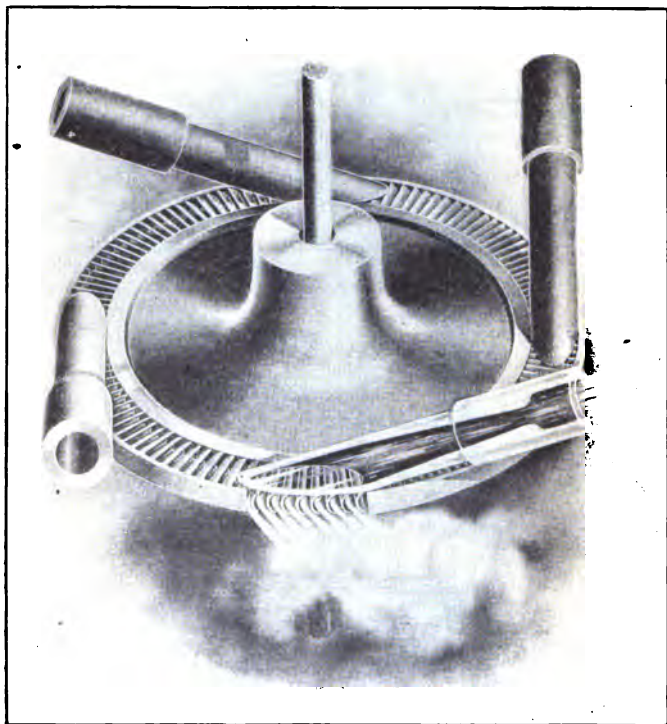
CARE AND OPERATION.

Owing to small clearances great care should be taken in warming up turbines. They should be warmed up for about two hours before getting under way, and jacked over one-fourth turn about every 15 minutes. If the turbines are not jacked the rotor will become distorted and serious damage follow. It is better not to warm the turbines at all than to do so without jacking over. They should never be started up cold except in case of emergency.

Turbines should be thoroughly drained when secured and should be drained frequently when idle by running the main air pump for about one-half hour or using the turbine drain pump when fitted.

Sketch 60 (see p. 147) shows a Curtis turbine.

Sketch 61 (see p. 148) shows the principle of the De Laval turbine.



SKETCH 61.

PART XI.

INTERNAL COMBUSTION ENGINES.

SECTION 1. GENERAL DISCUSSION.

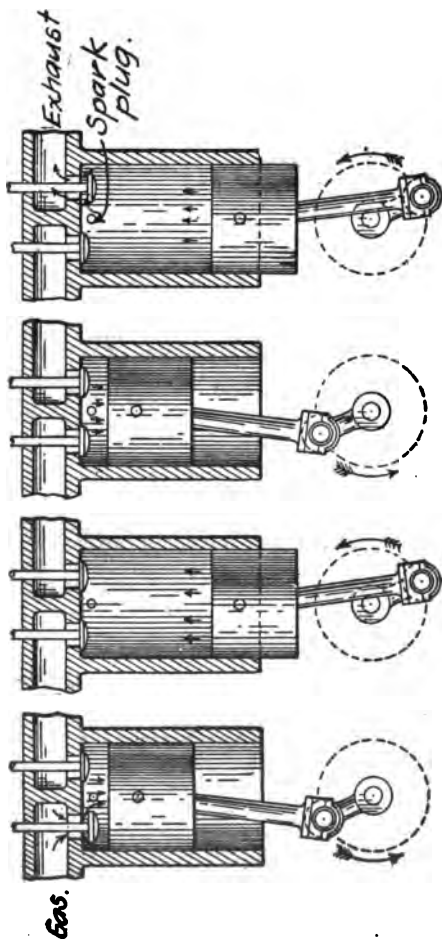
It is well understood that in the steam engine the combustion of the fuel takes place entirely outside the cylinders, in the furnaces of a separate boiler, through the walls of which the heat of combustion is transmitted to vaporize water, the resulting steam being then carried by suitable piping to the cylinders; in other words, it is an external combustion engine. Another form of heat engine is that in which the combustion or burning of the fuel takes place within the cylinder itself, the products of combustion acting directly on the pistons. This form is known as the internal combustion engine, explosion engine, gas or oil engine, and is so constructed that the equivalent of furnace, boiler, and cylinder is all complete in one, and on the same foundation. The principles governing the action of a gas engine or motor are practically the same as those of the steam engine; the object in both being the production of useful work from the heat evolved in the combustion of a fuel; in one case by the conversion of a gas into flame, and in the other water into steam, and in both cases utilizing the high pressures produced in the operation.

SEC. 2. SINGLE-ACTING, FOUR-CYCLE, GAS ENGINE.

In this type of engine it is necessary to make four complete strokes from end of the cylinder to the other; that is, two complete revolutions before an explosion or impulse against the piston is obtained. The steps performed on each separate stroke are shown in sketch 62, below:

In the above sketch—

Stroke 1. Charging.—The crank is shown rotating to the left by the arrow and the piston is descending which creates a vacuum or vacancy in the cylinder. The "gas" valve opens and the charge is sucked into the cylinder. The exhaust valve is held closed by its mechanism. There is no spark at the "spark plug." We now have the cylinder full of a charge consisting of gasoline and air well mixed, but at a very low pressure.



Stroke 2. Compressing.—The crank continuing in its rotation to the left now shoves the piston up, and as the two valves are closed the charge of air and gasoline vapor is compressed up to a high pressure.

Stroke 3. Explosion—Expansion.—When the piston has reached or has nearly reached the top of its second stroke contact is made to complete the electrical circuit in which the spark plug is the important item. This causes a spark, igniting the charge, which explodes, creating a still higher pressure, and this high pressure acting against the top of the piston shoves it down with increased speed and force. This leaves the cylinder full of burned gases that must be removed before a new charge can be drawn in.

Stroke 4. Exhaust.—
The piston returns again to the top, and in doing so shoves the burnt gases out of the open exhaust valve.

SEC. 3. SINGLE-ACTING, TWO-CYCLE, GAS ENGINE.

Navy type gasoline engines are of the two-cycle, three-port type, the action of which is as follows (figs. 1 and 2, sketch 63).

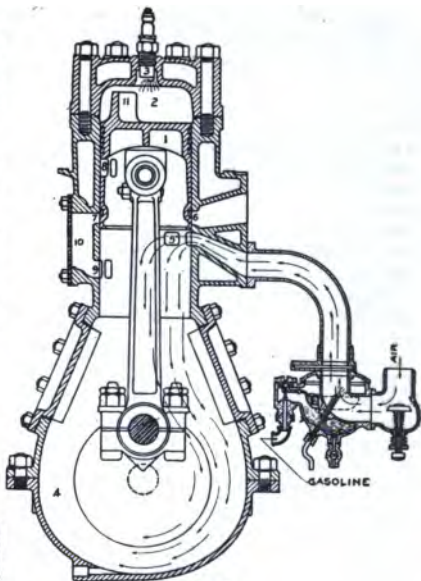


Fig. 1.

Consider the piston, 1, at the top of its stroke with the combustible charge of gas compressed and ready for ignition. On the first stroke the charge in the combustion chamber, 2, is ignited by the spark, 3, and burned, and the resulting increased pressure forces the piston downward. At the beginning of this stroke the inclosed crank case, 4, is full of

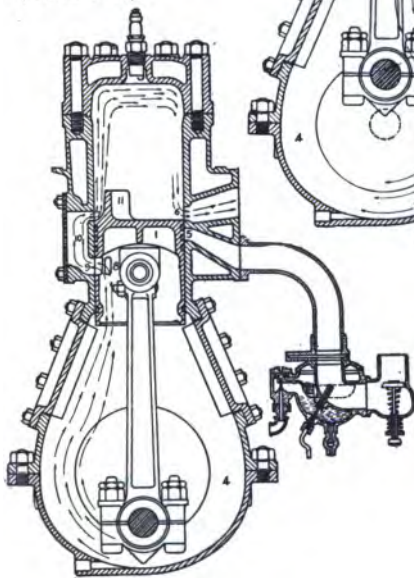


Fig. 2.

a combustible mixture which has been previously drawn in through ports, 5, and which is compressed to about 4 or 5 pounds by the piston on its down stroke. When near the bottom of the stroke the top edge of the piston uncovers a series of ports, 6, in the cylinder wall, through which the burned gases escape into the exhaust pipe, the pressure in the cylinder dropping to about that of the atmosphere. Shortly after the exhaust ports, 6, have been uncovered, the piston, still moving downward, uncovers the transfer ports, 7, in the cylinder wall, which are situated diametrically opposite the exhaust ports. The transfer of the mixture from the crank case into the cylinder is made through ports, 8, in the piston, which register with ports, 9, in the cylinder wall and admit the mixture into the by-pass, 10, from whence it passes into the cylinder through ports, 7. Ports, 7 and 9, open and close simultaneously. To prevent the incoming charge from passing directly across the cylinder and out of the exhaust ports, 6 (transfer and exhaust ports being open at the same time), the top of the piston is provided with a deflector or baffle plate, 11, which directs the charge up to the top of the cylinder, thereby driving out the greater part of the burned gases remaining therein. On the second stroke the piston moves upward, first closing the transfer ports, 7, and shortly after the exhaust ports, 6. The charge in the cylinder is compressed and at the top of the stroke is ready for firing. During this stroke a new charge is drawn into the crank case through ports, 5, in the cylinder wall, which are uncovered by the bottom edge of the piston, 1, when at the top of its stroke. On a three-port engine no check valve is required between the carburetor and the engine.

In practice the spark does not occur just at the moment the piston reaches the top of the stroke except when starting the engine, for the reason that the full firing of a combustible charge is not instantaneous at the time of ignition; therefore, in order to get the highest pressure and complete combustion when the piston is at the top of its stroke ignition must take place a little in advance, depending on the speed of the engine.

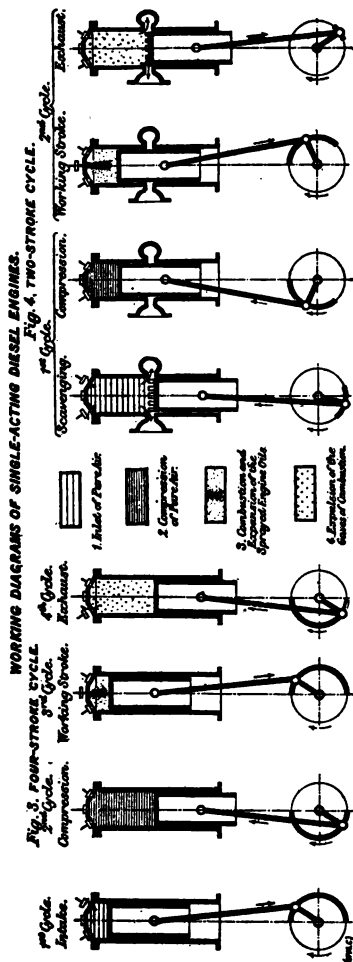
SEC. 4. DIESEL ENGINE.

Sketch 64 shows the principle of the Diesel engine, figure 3 showing the 4-cycle and figure 4 the 2-cycle engine. In figure 3 the valve on the left is the exhaust valve, the valve on the right is the air-admission valve, and the center valve is the fuel-injection

valve. There is no spark plug. Referring to figure 3, in compressing the air on the second cycle its temperature is raised above the ignition point of the oil used; then, when the fuel-injection-valve is opened the charge of fuel oil is sprayed into the cylinder by air compressed to a high pressure in an auxiliary air compressor. As soon as the oil enters the cylinder, it begins to burn and the gases formed expand and drive the piston downward on the working stroke. After the working stroke is completed the piston moves up on the exhaust stroke, driving the gases out through the exhaust valve.

In the 2-cycle engine, shown in figure 4, the principle is the same. The two side valves at the top of the cylinder are air-admission valves, the center one is the fuel-injection valve, and the exhaust takes place through the ports in the lower part of the cylinder.

When the working stroke is completed the piston uncovers the exhaust ports and the air-admission valves open, admitting air, which drives the spent gases out of the cylinder. Then the piston starts on the upstroke, the



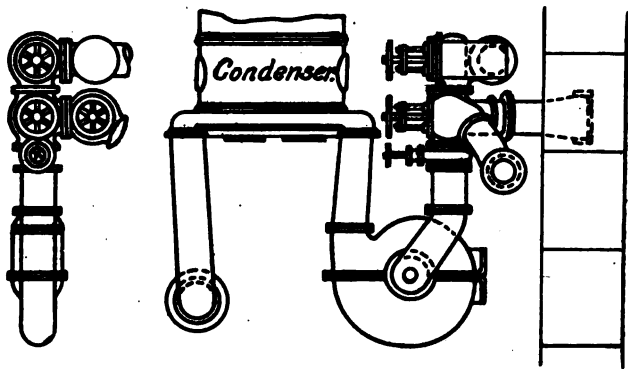
valves close, and the air in the cylinder is compressed. When the piston is near the top of its stroke the fuel-injection valve opens, fuel is sprayed in, combustion takes place, and the expanding gases drive the piston downward on the working stroke. In figure 4 the working stroke, exhaust, and scavenging are all parts of the same stroke, so that there is one working stroke in every revolution of the engine.

PART XII.

AUXILIARIES.

SECTION 1. THE MAIN CONDENSER.

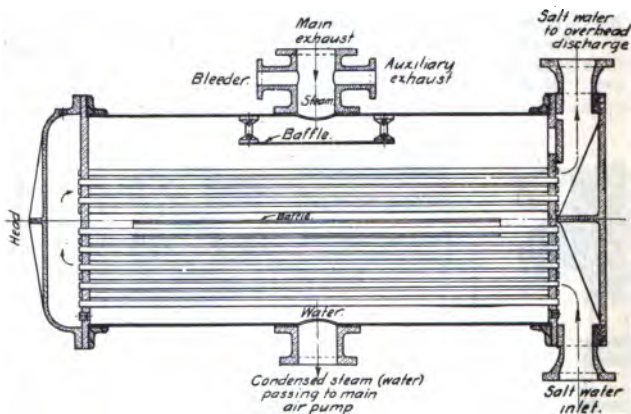
The purpose of the main condenser, as stated elsewhere in this book, is to change the steam after it has gone through the main engines back into water, in order that it may be used again in the boilers. Sketch 65 shows the connections of the main circulating pump to the main condenser; also showing the leads of the piping



SKETCH 65.

to the overboard discharge valve and from the main injection valve. It also has a connection to the main drain. The main circulating pump is nothing more than a huge fan which is made to rotate inside a case, and in doing so whips up the water coming in from the main injection valves and ("slings") forces the water through the tubes inside the main condenser and then out through the overboard-discharge valve.

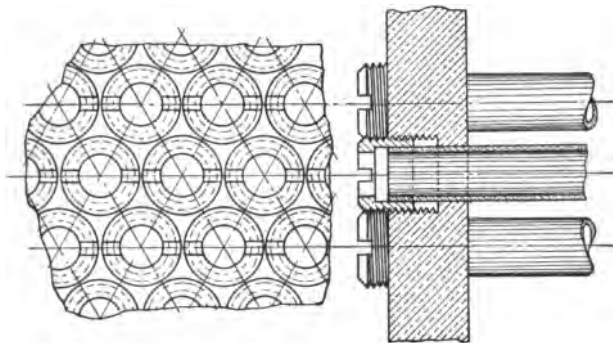
The following sketch (sketch 66) illustrates a main condenser, known as a surface condenser, and shows the connections of the various pipes, discharges, and suction to and from it. The main condenser consists of a shell, closed at each end by heads, and these heads are cross connected by the tubes. The cooling water enters at the lower right-hand corner from the main circulating pump, as shown by the arrows. This water passes through the lower set of tubes, condensing any steam that strikes the outside of these tubes into water, and in the left-hand "head" the direc-



SKETCH 66.

tion of this cooling water is reversed, causing it to flow back through the upper rows of tubes, likewise condensing steam, and then up and out through the pipes leading to the overboard discharge. The steam enters from the pipes at the top of the condenser, as shown, "bleeder," auxiliary exhaust, or main exhaust, and on striking the baffle is spread over a large area of the tubes. These tubes, kept cool by the circulating, condense the steam into water. The condensed steam falls to the bottom, as shown, and is removed from the condenser by the main air pump, which pumps the water into the feed tank or hot well.

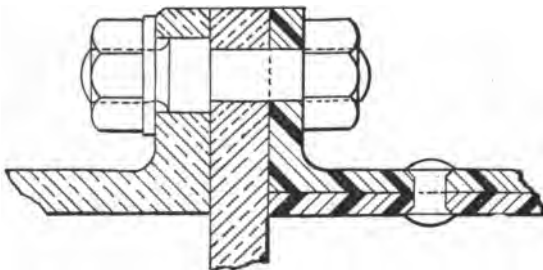
Sketch 67 shows the method of packing the tubes in order to prevent leakage of salt water into the condenser. The tubes and tube sheets are of composition to prevent corrosive action. Each tube is packed with cotton tape inserted around the tube at the bottom of the counterbore in the tube sheet, the screwed glands,



SKETCH 67.

as shown, fitting around the tube are screwed into the tube sheet, compressing the packing and making it water-tight.

Sketch 68 shows the method of securing the tube sheets.



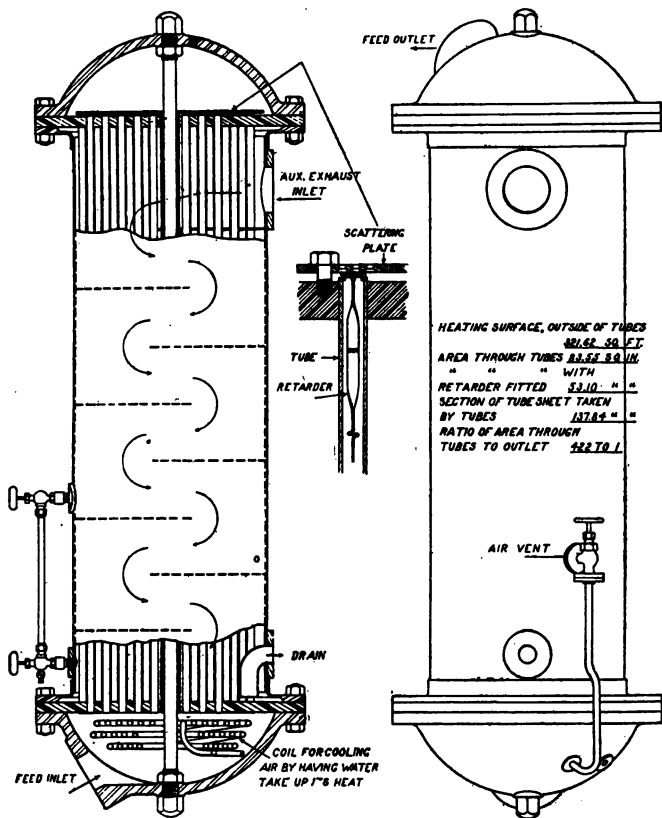
SKETCH 68.

SEC. 2. FEED-WATER HEATER.

A feed-water heater is for the purpose of heating the water that is to be fed the boilers by the main feed pumps. This heating of the water nearly up to the boiling point saves in coal and requires less heat absorption in the boilers for making steam. Sketch 69 (see p. 159) shows a vertical single flow feed-water heater. The cold water enters at the bottom from the feed tank and passing up through the heater tubes that are kept hot by the steam entering as shown by the arrows, leave the heater at the top, with a much higher (hotter) temperature than on entrance. This water is forced by the feed pumps through the heater into the boilers for steam-making purposes. The heater is fitted with a steam-pressure gauge and a trap as shown. Generally steam from the auxiliary exhaust is used in the heater; in some cases live steam from the main or auxiliary steam line is used. Feed heaters are made in many forms. The one shown here is illustrative of their main principles—i. e., to heat up the feed water for the boilers by taking the heat from a small supply of steam. The steam condenses in the heater and the water of condensation is trapped off at the bottom of the heater to the feed tank. The heater shown is called "single flow," as the water has only one direction in passing through it. The main feed pumps should be placed between the feed tank and the heater—i. e., the heater should be after the pumps in the circuit to the boilers, thus: Feed tank, feed pumps, feed heater, then boilers, as this will permit the pumps handling the colder water before it has been heated in the feed-water heater.

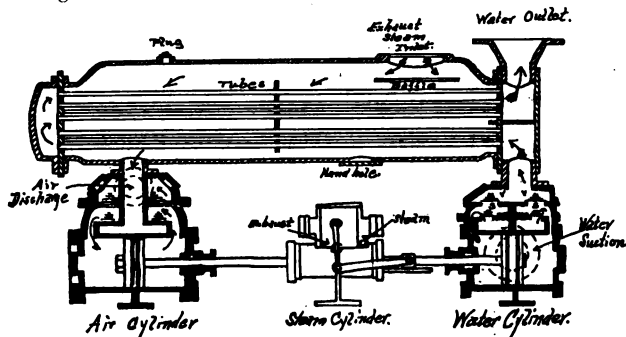
SEC. 3. AUXILIARY CONDENSER.

The auxiliary condenser is used for condensing the exhaust steam from the auxiliaries when the main condenser is secured. It is a complete unit in itself, having its own air pump and its own circulating pump. Sketch 70, below, shows an auxiliary condenser with all its connections. The air and circulating pumps are of the ordinary piston type. In the water end, circulating pump, on each stroke suction occurs in one end, while the other end is forcing water through the tubes to condense the steam. On each stroke of the air pump one end sucks in the condensed steam, while the other end is discharging the water of condensation into the feed tank or hot well. The tubes and tube sheets are secured in a manner similar to those in the main condenser. An air cock is fitted to this condenser for relieving any air that may accumulate in it. The pumps are worked by the small steam cylinder shown with its valve



SKETCH 69.

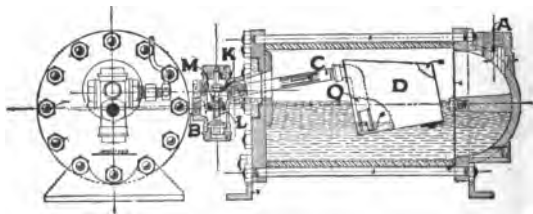
gear. On large ships there is generally one auxiliary condenser in each engine room.



SKETCH 70.

SEC. 4. STEAM TRAP.

Sketch 71 shows the Lytton bucket trap, which is of the intermittent-flow type. It consists of a chamber, a bucket, a main and an auxiliary valve. Discharge pipes lead to and from the chamber and valve chest, respectively. Water and steam flow through the inlet opening, *A*, to the chamber and raise the bucket,



SKETCH 71.

D, until it strikes the top of the chamber. When the water rises to the top of *D* it overflows into it. The bucket, *D*, then fills and drops to the bottom of the chamber. This causes an upward movement of the lever, *K*, which raises the auxiliary valve, *M*, and admits the pressure in the trap to the underside of the piston attached to the main valve, *L*. This pressure opens the main valve

and the water is forced out of the trap through bucket, *D*, connection, *Q*, to pipe, *C*, and thence to outlet, *B*. The water flows from the trap chamber until level with the top of *D*, when it is at its lowest position; then that in *D* is blown out until *D* floats (in the position shown) and closes the valves *L* and *M*. *L* and *M* remain closed until *D* fills and drops again. All parts of this trap except the float are outside of the chamber and are accessible. All of the automatic functions of the trap can be performed by hand from the outside by means of the lever shown in the end view. The bucket or intermittent flow trap is the only one used in the Navy.

SEC. 5. GREASE EXTRACTORS.

Grease extractors, for extracting the grease from the feed water for boilers, are made similar to Macomb strainer previously described. The cartridge is perforated and covered with burlap through which the water filters. It is placed on the discharge side of the main feed pump generally, and is fitted with a by-pass valve, so that the extractors may be overhauled without interrupting the feed. An intermediate tank, called the hot-well tank, is frequently placed between the air pump and the filter and feed tank, so that in case the filtering bed becomes clogged up it will not bring too great a strain on the air pump. In this case a small pump called the hot-well pump, is supplied to pump the water from the hot-well tank to the filter. An escape pipe and valve are provided, so that in case of derangement the valve will lift and the water pass directly to the feed tank.

SEC. 6. RESERVE FEED TANKS.

To make up the unavoidable losses of fresh water about the engines and boilers it is necessary to have reserve tanks from which the "make-up" feed may be taken. The double bottoms under the engine and fire rooms are usually used for this purpose, filled when in port with fresh water from a water boat, and from the distiller and evaporating plant on the ship. Connections are made to the air pump, to an auxiliary feed-pump suction, or to a small double-bottom pump; this latter pumping directly from the double bottom to the feed tank.

SEC. 7. FEED WATER FILTERS.

In order to remove oil or grease from the feed water before it enters the boilers and to avoid its destructive effect, feed-water

filters are employed. In the United States Navy a filter tank is usually employed in connection with and a part of the feed tank. The part devoted to the feed-filter tank is usually divided by partitions into three chambers by means of perforated plates. In these chambers is placed the filtering material, consisting usually of some fibrous material, such as sponges, bagging, toweling, or a sea growth called "loofa." These materials collect the oil and impurities and before becoming clogged are removed, washed, and cleaned or renewed. The discharge from the air pumps lead into the filter tank through which the water flows to the feed tanks.

SEC. 8. ALLEN DENSE-AIR REFRIGERATION.

There are various systems of refrigeration, depending upon two general methods, one consisting of a change of state, physical, chemical, or both, and the other, the compression, cooling and expansion of an elastic gas, such as air. The cold-air system is based on the second principle, and cold-air machines are fitted on nearly all United States vessels. The working principles of the air-ice machines is based on the creation of heat during the compression of the air, and the creation of cold to about an equal amount during expansion. The machines, therefore, consist of an air compressor, which compresses the air and passes it into a cooling coil of pipe surrounded by circulating water. This cold water removes the heat of compression and passes the compressed cooled air to the expander, a regular cut-off steam engine into which the air is admitted during part of the stroke of the piston; the admission is then cut off and the air in the cylinder is expanded as the piston proceeds to finish its stroke. In doing this the air is cooled. During this expansion the air is cooled to a very low temperature, and the return stroke of the piston pushes it out, and pipes convey it to the place that is to be cooled by it. It is usual to take air from the atmosphere and to refrigerate it in the above manner. The American Allen dense air ice machine is the type used in the Navy. The machine is constructed to use an air pressure of 60 pounds in the conveying and refrigerating pipes, and the air compressor compresses this to about 250 pounds. If these pressures can not be maintained, it is an indication that leaks have occurred, and the piston packings and possibly the run of pipes have to be overhauled. If the trap or any portion of the piping is choked by frozen oil or snow, or by the closing of valves the pressure relation required will be changed. The cylinders require lubrication with the best quality of mineral lubricating oil. The air pistons are packed with leathers soaked in castor oil. The air stuffing boxes contain, first, a few turns of Katzenstein metallic pack-

ing rings, then a hollow oiling ring, then outer layers of fibrous packing, usually square Garlock. The oiling ring is kept full of oil by a sight-feed-pressure lubricator, which is connected to the stuffing box by a pipe. The air pushed out by the expander is commonly practically of about 35 to 55° temperature below zero (Fahrenheit), depending upon the temperature of the cooling water and upon internal leaks and frictions. The pipes lead it, first, through the oil trap, *E*, for purification, then to the ice-making box, *I*, which consists of a casting, forming pockets, *T*, for the reception of sheet-iron ice cans. This casting is set in a strong and tight jacket casting with internal bulkheads, formed so that the cold air which is led into the space between jacket and ice-can pockets must pass closely along the surfaces of the pockets. The small space between the sheet-iron ice cans and the inside of the pockets is filled with a solution of about equal weights of chloride of calcium and water which withstands the cold without freezing. (Note: If you run out of this solution use the brine from the evaporators.) It provides a good conductor for the cold and keeps the cans from freezing fast in the pockets. From the ice-making box the cold air is led to the cold-storage chamber, *K*, where it is passed through a system of refrigerating pipes, *L*. Frozen meat can be kept practically without change for an indefinite time. When kept at nearly the freezing point without change it may be kept for a number of weeks in good condition. From the cold storage the cold air goes to the refrigerating pipes in the drinking water butt, *M*, passing first to the bottom layer and then gradually upward.

Once or twice each day it is necessary to clean the machine by heating it up and blowing out all the oil and ice deposits. This is done as follows: The 1-inch valve of the by-pass is opened. Then the two 1½ or 2 inch valves in the main pipes are closed; then the two 1½-inch valves in the hot-air pipe from the compressor chest to the expander are opened, and the 1½-inch valve of the expander inlet is partly closed; then the live steam is let into the jacket of the oil trap slowly, keeping the outlet from the steam jacket open enough to drain the condensed steam.

Run in this manner for about one-half hour. During this time frequently blow out the bottom valve of the oil trap, also the blow-off from the expander, until everything appears clean. Then shut off the steam and drain connections of the jacket of the trap and the hot-air pipe from the compressor to the expander. Then open the two 1½-inch valves in the main pipes. Then close the 1-inch by-pass pipe and all pet-cocks and run as usual. When opportunity offers to blow out the manifolds of the cold storage and the ice-making box this should be done.

DIRECTIONS FOR OPERATING.

On starting the machine have the blow valves of the expander and the pet cocks of the various traps open until no more grease or water discharges.

The two $1\frac{1}{2}$ inch or 2-inch valves of the main pipes must be open and the 1-inch by-pass pipe closed; also the $\frac{1}{2}$ -inch hot-air valves from the compressor to the expander cylinder must be closed.

Be sure that the circulating water is in motion.

The full pressure is 60 to 70 pounds low pressure and 220 to 250 pounds high pressure.

During the running, open the pet cocks of the water trap which takes the water out of the air from the primer pump frequently enough not to let it fill over half way. If the water should be allowed to enter the main pipes it is liable to freeze and clog at the valves.

By keeping all stuffing boxes well lubricated by the lubricator cups, the pressures are easily maintained with but little screwing up of the packings.

If the low-pressure air pressure is not maintained the fault is almost always due to leaks through the stuffing boxes. Under all circumstances it is due to some leak into the atmosphere, as the primer pump valves have been rarely found at fault.

The pistons of the compressor and expander cylinders are packed with cup leathers, which generally last about one or two months of steady work. When these leathers give out the high pressure decreases in relation to the low pressure, and the apparatus shows a loss of cold. A leak at any other point of high pressure into low pressure will have the same effect.

These packing leathers are made of white oak tanned leather of somewhat less than $\frac{1}{8}$ inch thickness. They are cut $\frac{1}{8}$ inch larger in diameter than the cylinders. The leathers must be kept soaked in castor oil and must be well soaked in that before using. A tin box containing spare leathers soaked in oil must be kept on hand.

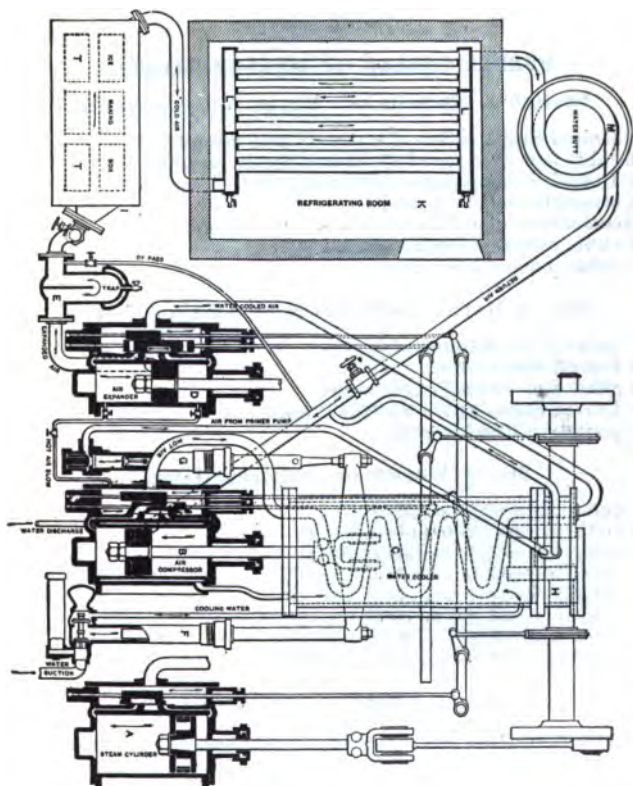
Referring to the sketch 72, the machine consists of the following parts:

A. The steam cylinder, which furnishes all power needed. To its crank shaft the air compressor and expander are linked.

B. The air compressor cylinder; compresses the air. This cylinder is water jacketed.

C. A copper coil in a bath of water. The hot air after compression passes through this coil which cools the air to the temperature of the surrounding circulating water.

D. Expander cylinder. Here the cooled compressed air is expanded and further cooled to a very low temperature.



SKETCH 72.

E. Trap which collects the lubricating oil used in the cylinders; also collects snow. It can be thawed and blown out.

PART XIII.

USEFUL TABLES OF MEASUREMENTS.

SECTION 1. ENGLISH AND METRIC MEASUREMENTS.

1 United States gallon of water=8.3356 pounds.
1 cubic foot of water=7.48 United States gallons.
1 United States gallon=.1337 cubic foot.
1 atmosphere=14.7 pounds.
Acceleration of gravity=32.16 feet per second=g.
1 cubic meter=1,000 kilograms.
1 cubic meter=1,000 liters.

SEC. 2. METRIC EQUIVALENTS OF ENGLISH UNITS.

1 inch=2.54 centimeters.
1 foot=0.3048 meter.
1 cubic foot=0.0283 cubic meter.
1 United States gallon=3.7854 liters.
1 pound=0.4536 kilogram.

SEC. 3. WEIGHT OF DISTILLED WATER.

1 cubic foot=62.5 pounds at 0° F.
1 cubic foot=62.2 pounds at 80° F.
1 cubic foot=62.1 pounds at 90° F.
1 cubic foot=62.0 pounds at 100° F.
1 cubic foot=61.7 pounds at 120° F.
1 cubic foot=61.2 pounds at 150° F.
1 cubic foot=60.6 pounds at 180° F.
1 cubic foot=59.84 pounds at 212° F.

SEC. 4. WEIGHT OF SEA WATER.

Sea water weights 64.1 pounds per cubic foot.

SEC. 5. LINEAR, SQUARE, AND CUBIC MEASURES.

12 inches=1 foot (ft.).
 3 feet=1 yard (yd.).
 6 feet or 2 yards=1 fathom (fth.).
 1,760 yards=1 land mile (mile).
 5,280 feet=1 land mile (mile).
 6,080 feet=1 knot (kt.).
 144 square inches=1 square foot.
 9 square feet=1 square yard.
 3,097,600 square yards=1 square mile.
 1,728 cubic inches=1 cubic foot=7.4805 gallons.
 27 cubic feet=1 cubic yard.

SEC. 6. LIQUID MEASURES.

4 gills=1 pint=34.659 cubic inches.
 2 pints=1 quart=69.318 cubic inches.
 4 quarts=1 gallon=277.274 cubic inches.
 8 gallons=1 bushel=1.283 cubic feet.
 1 United States gallon=231 cubic inches.

SEC. 7. WEIGHTS OF OIL AT 32° F. IN POUNDS.

Name.	1 cubic foot.	1 United States gallon.	Cubic feet per ton.
Cotton seed.....	58.0	7.761	38.62
Linseed.....	58.6	7.844	38.22
Petroleum.....	55.5	7.427	40.34
Cylinder oil.....	56.8	7.594	39.42
Heavy lubrication.....	56.5	7.552	39.64
Light lubrication.....	55.9	7.469	40.07
Sperm oil.....	54.9	7.344	40.78
Turpentine.....	54.3	7.260	41.25

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SEC. 8. SQUARES AND CUBES.

For finding areas and volumes from 0.1 to 100.

No.	Square.	Cube.	No.	Square.	Cube.
0.1.....	0.01	0.001	3.5.....	12.25	42.875
0.15.....	.0225	.0034	3.6.....	12.96	46.656
0.2.....	.04	.008	3.7.....	13.69	50.653
0.25.....	.0625	.0156	3.8.....	14.44	54.872
0.3.....	.09	.027	3.9.....	15.21	59.319
0.35.....	.1225	.0429	4.0.....	16.00	64.000
0.4.....	.16	.064	4.1.....	16.81	68.921
0.45.....	.2025	.0911	4.2.....	17.64	74.088
0.5.....	.25	.125	4.3.....	18.49	79.507
0.55.....	.3025	.1664	4.4.....	19.36	85.184
0.6.....	.36	.216	4.5.....	20.25	91.125
0.65.....	.4225	.2746	4.6.....	21.16	97.336
0.7.....	.49	.343	4.7.....	22.09	103.823
0.75.....	.5625	.4219	4.8.....	23.04	110.592
0.8.....	.64	.512	5.0.....	25.00	125.000
0.85.....	.7225	.6141	5.1.....	26.01	132.651
0.9.....	.81	.729	5.2.....	27.04	140.608
0.95.....	.9025	.8574	5.3.....	28.09	148.877
1.00.....	1.0000	1.00	5.4.....	29.16	157.464
1.05.....	1.1025	1.158	5.5.....	30.25	166.375
1.1.....	1.21	1.331	5.6.....	31.36	175.616
1.15.....	1.3225	1.521	5.7.....	32.49	185.193
1.2.....	1.44	1.728	5.8.....	33.64	195.112
1.25.....	1.5625	1.953	5.9.....	34.81	205.397
1.3.....	1.69	2.197	6.0.....	36.00	216.000
1.35.....	1.8225	2.460	6.1.....	37.21	226.981
1.4.....	1.96	2.744	6.2.....	38.44	238.328
1.45.....	2.1025	3.049	6.3.....	39.69	250.047
1.5.....	2.25	3.375	6.4.....	40.96	262.144
1.55.....	2.4025	3.724	6.5.....	42.25	274.625
1.6.....	2.56	4.096	6.6.....	43.56	287.496
1.65.....	2.7225	4.492	6.7.....	44.89	300.763
1.7.....	2.89	4.913	6.8.....	46.24	314.432
1.75.....	3.0625	5.359	6.9.....	47.61	328.509
1.8.....	3.24	5.832	7.0.....	49.00	343.000
1.85.....	3.4225	6.332	7.1.....	50.41	357.911
1.9.....	3.61	6.859	7.2.....	51.84	373.248
1.95.....	3.8025	7.415	7.3.....	53.29	389.017
2.....	4	8	7.4.....	54.76	405.224
2.1.....	4.41	9.261	7.5.....	56.25	421.875
2.2.....	4.84	10.648	7.6.....	57.76	438.976
2.3.....	5.29	12.165	7.7.....	59.29	456.533
2.4.....	5.76	13.824	7.8.....	60.84	474.552
2.5.....	6.25	15.625	7.9.....	62.41	493.039
2.6.....	6.76	17.576	8.0.....	64.00	512.000
2.7.....	7.29	19.683	8.1.....	65.61	531.441
2.8.....	7.84	21.952	8.2.....	67.24	551.368
2.9.....	8.41	24.389	8.3.....	68.89	571.787
3.0.....	9.00	27.000	8.4.....	70.56	592.704
3.1.....	9.61	29.791	8.5.....	72.25	614.125
3.2.....	10.24	32.768	8.6.....	73.96	636.056
3.3.....	10.89	35.937	8.7.....	75.69	658.503
3.4.....	11.56	39.304	8.8.....	77.44	681.472

SEC. 8. SQUARES AND CUBES—Continued.

For finding areas and volumes from 0.1 to 100—Continued.

No.	Square.	Cube.	No.	Square.	Cube.
8.9.....	79.21	704.969	50.....	2500	125000
9.0.....	81.00	729.000	51.....	2601	132651
9.1.....	82.81	753.571	52.....	2704	140608
9.2.....	84.64	778.688	53.....	2809	148877
9.3.....	86.49	804.357	54.....	2916	157464
9.4.....	88.36	830.584	55.....	3025	166375
9.5.....	90.25	857.375	56.....	3136	175616
9.6.....	92.16	884.736	57.....	3249	185193
9.7.....	94.09	912.673	58.....	3364	195112
9.8.....	96.04	941.192	59.....	3481	205379
9.9.....	98.01	970.299	60.....	3600	216000
10.....	100	1000	61.....	3721	226981
11.....	121	1331	62.....	3844	238328
12.....	144	1728	63.....	3969	250047
13.....	169	2197	64.....	4096	262144
14.....	196	2744	65.....	4225	274625
15.....	225	3375	66.....	4356	287496
16.....	256	4096	67.....	4489	300768
17.....	289	4913	68.....	4624	314432
18.....	324	5832	69.....	4761	328509
19.....	361	6859	70.....	4900	343000
20.....	400	8000	71.....	5041	357911
21.....	441	9261	72.....	5184	373248
22.....	484	10648	73.....	5329	389017
23.....	529	12167	74.....	5476	405224
24.....	576	13824	75.....	5625	421875
25.....	625	15625	76.....	5776	438976
26.....	676	17576	77.....	5929	456533
27.....	729	19683	78.....	6084	474552
28.....	784	21952	79.....	6241	493039
29.....	841	24389	80.....	6400	512000
30.....	900	27000	81.....	6561	531441
31.....	961	29791	82.....	6724	551368
32.....	1024	32768	83.....	6889	571787
33.....	1089	35937	84.....	7056	592704
34.....	1156	39304	85.....	7225	614125
35.....	1225	42875	86.....	7396	636056
36.....	1296	46656	87.....	7569	658503
37.....	1369	50653	88.....	7744	681472
38.....	1444	54872	89.....	7921	704969
39.....	1521	59319	90.....	8100	729000
40.....	1600	64000	91.....	8281	753571
41.....	1681	68921	92.....	8464	778688
42.....	1764	74088	93.....	8649	804357
43.....	1849	79507	94.....	8836	830584
44.....	1936	85184	95.....	9025	857375
45.....	2025	91125	96.....	9216	884736
46.....	2116	97336	97.....	9409	912673
47.....	2209	103823	98.....	9604	941192
48.....	2304	110592	99.....	9801	970299
49.....	2401	117649	100.....	10000	1000000

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SEC. 9.—AREAS AND CIRCUMFERENCES.

For computing indicator cards 10 to 80 inches diameters.

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
10.....	31.416	78.54	11.....	34.558	95.08
10 $\frac{1}{2}$	81.809	80.52	11 $\frac{1}{2}$	34.960	97.21
10 $\frac{3}{4}$	82.201	82.52	11 $\frac{3}{4}$	35.243	99.40
10 $\frac{1}{2}$	82.594	84.54	11 $\frac{1}{2}$	35.736	101.82
10 $\frac{3}{4}$	82.987	86.59	11 $\frac{3}{4}$	36.128	103.87
10 $\frac{1}{2}$	83.379	88.66	11 $\frac{1}{2}$	36.521	106.14
10 $\frac{3}{4}$	83.772	90.76	11 $\frac{3}{4}$	36.914	108.43
10 $\frac{1}{2}$	84.165	92.89	11 $\frac{1}{2}$	37.306	110.75
12.....	37.699	113.10	13.....	40.841	132.73
12 $\frac{1}{2}$	38.485	117.86	13 $\frac{1}{2}$	41.626	137.89
12 $\frac{3}{4}$	39.270	122.72	13 $\frac{3}{4}$	42.412	143.14
12 $\frac{1}{2}$	40.065	127.68	13 $\frac{1}{2}$	43.197	148.40
14.....	43.982	153.94	15.....	47.124	176.71
14 $\frac{1}{2}$	45.553	165.13	15 $\frac{1}{2}$	48.695	198.69
16.....	50.265	201.06	17.....	53.407	226.96
16 $\frac{1}{2}$	56.549	254.47	19.....	59.690	283.53
20.....	62.832	314.16	21.....	65.973	346.36
22.....	69.115	380.13	23.....	72.257	415.48
24.....	75.398	452.39	25.....	78.540	490.87
26.....	81.681	530.93	27.....	84.823	572.56
28.....	87.965	615.75	29.....	91.106	660.52
30.....	94.248	706.86	31.....	97.389	754.77
32.....	100.531	804.25	33.....	103.673	855.30
34.....	106.814	907.92	35.....	109.956	962.11
36.....	113.097	1,017.00	37.....	116.239	1,075.2
38.....	119.381	1,134.1	39.....	122.522	1,194.6
40.....	125.664	1,256.6	41.....	128.805	1,320.3
42.....	131.947	1,385.4	43.....	135.088	1,452.2
44.....	138.230	1,520.5	45.....	141.372	1,590.4
46.....	144.513	1,661.9	47.....	147.655	1,734.9
48.....	150.796	1,809.6	49.....	153.938	1,885.7
50.....	157.080	1,963.5	51.....	160.221	2,042.8
52.....	163.363	2,123.7	53.....	166.504	2,206.2
54.....	169.646	2,290.2	55.....	172.788	2,375.8
56.....	175.929	2,463.0	57.....	179.071	2,551.8
58.....	182.212	2,642.1	59.....	185.354	2,734.0
60.....	188.496	2,827.4	61.....	191.637	2,922.5
62.....	194.779	3,019.1	63.....	197.920	3,117.2
64.....	201.062	3,217.0	65.....	204.204	3,318.3
66.....	207.345	3,421.2	67.....	210.487	3,525.7
68.....	213.628	3,631.7	69.....	216.770	3,739.3
70.....	219.911	3,848.5	71.....	223.053	3,959.2
72.....	226.195	4,071.5	73.....	229.336	4,185.4
74.....	232.478	4,300.8	75.....	235.619	4,417.9
76.....	238.761	4,536.5	77.....	241.903	4,656.6
78.....	245.044	4,778.5	79.....	248.186	4,901.7
80.....	251.327	5,026.5	81.....	254.469	5,153.0

APPENDIX I.

In order to give enlisted men an idea of the requirements to be fulfilled to obtain entrance to the United States Naval Academy, Annapolis, Md., this appendix has been added. The physical examination is similar to the one given on enlistment and enlisted men should find no difficulty in passing it.

SAMPLE MENTAL ENTRANCE EXAMINATION.

DICTATION EXERCISE IN SPELLING.

The examiner will pronounce distinctly each word, repeating the word if necessary.

Twenty minutes are allowed for this subject.

- | | | |
|-----------------|------------------|--------------------|
| 1. confidence. | 18. pendulum. | 35. deceive. |
| 2. poison. | 19. ornamental. | 36. museum. |
| 3. argument. | 20. absolute. | 37. motor. |
| 4. acclamation. | 21. drama. | 38. motley. |
| 5. onion. | 22. sphere. | 39. malign. |
| 6. vegetable. | 23. volume. | 40. intestine. |
| 7. dictionary. | 24. mistress. | 41. university. |
| 8. accessible. | 25. cabinet. | 42. comprehend. |
| 9. photography. | 26. secretary. | 43. merit. |
| 10. radiant. | 27. opportunity. | 44. library. |
| 11. solar. | 28. ballast. | 45. trough. |
| 12. bankrupt. | 29. electric. | 46. indispensable. |
| 13. brilliant. | 30. station. | 47. discriminate. |
| 14. currency. | 31. reality. | 48. value. |
| 15. uniform. | 32. friction. | 49. notable. |
| 16. revolution. | 33. pulley. | 50. indelible. |
| 17. recompense. | 34. wheedle. | |

GRAMMAR.

Question 1. Punctuate the following, and insert capitals where needed:

in his message to congress dec 2 1913 president wilson said gentlemen of the congress in pursuance of my constitutional duty to give to the congress information of the state of the union i take the liberty of addressing you on several matters which ought as it

seems to me particularly to engage the attention of your honorable bodies as of all who study the welfare and progress of the nation

Question 2. (a) Fill each blank with *who* or *whom*, as the construction may require:

1. He asked me ——— was elected.
2. ——— do you regard as the better scholar of the two?
3. ——— do you think is the best physician in town?
4. He was put through college by his uncle, for ——— he had a strong dislike, and ———, he said, treated him like a dog.

(b) Correct, if necessary, the following sentences:

1. We will perish; nothing can help us.
2. Each of us should do their best.
3. William is better at his lessons than me.
4. Can I borrow your pen? I will return it.

Question 3. Analyze the following sentence, and parse the italicized words: "*When they saw the ship they shouted joyfully, and some of them burst into tears.*"

Question 4. (a) Write sentences to illustrate (1) indirect object of a transitive verb, (2) infinitive used as a subject, (3) a collective noun modified by a present participle, (4) a clause used as the direct object of a verb.

(b) Give the past tense and past participle of the following: Drink; fling; flee; begin; bring; burst; throw; lie (to recline); lay.

Question 5. Write a theme of at least one page (about 300 words) on one of the following subjects:

1. An incident in the life of a great man.
2. A pleasure trip.
3. A description of some character in fiction.

UNITED STATES HISTORY.

Question 1. (a) Discuss English explorations in the seventeenth century.

(b) Discuss briefly the colonial governments prior to the Revolution.

Question 2. (a) Who was Thomas Jefferson, and what did he accomplish?

(b) Describe the battle of Saratoga and its effects on the war.

Question 3. (a) What is the Monroe Doctrine?

(b) Describe briefly the expansion of the United States by war, purchase, exploration, and treaty, from the time of the thirteen Colonies to the present day.

Question 4. (a) Sketch the life of one of the following men: (1) Lincoln; (2) Lee; (3) Grant; (4) Jackson ("Stonewall").

(b) What were the causes of the Spanish-American War?

Question 5. Discuss the significance of the Panama Canal.

GEOGRAPHY.

Question 1. (a) Fix the position of the following: (1) Saghalien; (2) Aberdeen; (3) Palermo; (4) Barcelona; (5) Balearic Islands; (6) Borneo; (7) Falkland Islands; (8) Halifax; (9) Winnipeg; (10) Magdalena Bay.

(b) To what nation or nations does each of the above belong?

Question 2. (a) Bound Illinois and Wyoming; give their population and capitals.

(b) Name in order the States of the United States that border the sea.

Question 3. (a) Describe the course (1) of the Colorado River, naming in order the States through which or between which it passes; (2) of the Tennessee River.

(b) Through what bodies of water would a vessel pass in making a voyage from Gibraltar to Vladivostok?

Question 4. Write a theme of at least one page on the State in which you live, and on one other of the United States, giving climate, population, principal products, capital, and chief towns.

ALGEBRA.

Time allowed, three hours.

Question 1. (a) Factor $a^3 + b^3$, $x^4 + y^4 - 7x^2y^2$, $51x^2 - 25x - 6$, $x^3 - (a+b+c)x^2 + (ab+ac+bc)x - abc$ and $3x^2 - 4ax - 2bx + a^2 + 2ab$.

(b) Multiply $2a - a\frac{1}{3} + 3a - \frac{1}{3}$ by $3a - 2a\frac{1}{3} - 2a - \frac{1}{3}$. Check the product by dividing it by $2a - a\frac{1}{3} + 3a - \frac{1}{3}$.

Question 2. (a) If flour costs b cents a pound and sugar c cents a pound, and if a man buys twice as many pounds of flour as of sugar, how many pounds of each can he buy with m dollars?

(b) Solve the simultaneous equations $ax + by = c$ and $dx + cy = f$.

(c) Rationalize the denominators and simplify $\frac{25\sqrt{3}-4\sqrt{2}}{7\sqrt{3}-5\sqrt{2}}$ and $\frac{2\sqrt{a+b}+3\sqrt{a-b}}{2\sqrt{a+b}-\sqrt{a-b}}$.

Question 3. (a) A field containing 1 acre is in the form of a rectangle $\frac{2}{3}$ as wide as it is long. The field is enlarged by adding 39,664 square feet in such a way as to increase length and width of the rectangle an equal amount. Find the dimensions of the enlarged field.

(b) Given $9x^2 + 2xy + y^2 - 92x - 20y + 244 = 0$, solve for x in terms of y . Between what limiting values of y is x real?

Question 4. (a) Solve the simultaneous equations $y^2 - x^2 = 16$ and $2y^2 - 4xy + 3x^2 = 17$, grouping the corresponding values of x and y . (b) The diagonal of a rectangle is 25 inches. If the rectangle were 4 inches shorter and 8 inches wider, the diagonal would still be 25 inches. Find the area of the rectangle.

Question 5. (a) In a hurdle race of 560 feet, A beats B by 70 feet. He then gives B a start of 40 feet and beats him by 2 seconds. Find the speed of each in feet per second.

(b) Solve the equations $3x^2 - 4x + \sqrt{3x^2 - 4x - 6} = 18$ and $3^2x + 9 = 10(3x)$.

GEOMETRY.

Time allowed, two hours.

N. B.—In solving problems the processes should not be merely indicated, but all the figures necessary in solving each problem should be given in full. Number the work and answers to correspond with the numbers of the questions. The answer to each problem should be indicated by writing "Ans." after it.

Do not write on this sheet. Blank sheets will be furnished for the answers to the questions hereon. Number answers to correspond with numbers of questions.

Write only on the ruled side of the blank sheets furnished.

Do not use a separate sheet of any kind for rough work. All work should be submitted in its original form. No smooth copy is required. Pencil may be used for all mathematical work.

1. (a) Name and define the different kinds of quadrilaterals, including the different kinds of parallelograms. Prove that the straight lines joining a pair of opposite vertices of a parallelogram to the midpoints of the opposite sides are equal and parallel.

(b) In a right triangle ABC a perpendicular is drawn from the right angle C to the hypotenuse c , dividing it into two segments x and y . Find the value of x and y in terms of a , b , and c , the three sides of the triangle, stating reasons for each step; thence deduce $a^2 + b^2 = c^2$.

2. (a) Show how to construct a triangle, given two sides a and b and the angle A opposite the side a .

(b) Define circle, and the secant, tangent, chord, sector, and segment of a circle. Prove that the tangent from a given point P to a circle is a mean proportional between the two segments of any secant drawn from P .

3. (a) A point P is 15 inches from the center of a given circle, and the segments of a given chord through P are 16 and 25 inches. Find the length of the longest and shortest chord through P , and also the length of a chord subtending an arc of 120° .

(b) What is the side of an equilateral triangle, the area of which is equivalent to the area of two similar triangles having sides of 33 and 56 inches, respectively.

4. (a) In a circle of 10 inches radius find the area of a segment cut off by a chord of 10 inches ($\pi=3.1416$).

(b) Find the area of a regular inscribed dodecagon in a circle of radius a .

5. (a) Find the side and area of the equilateral triangle inscribed in a circle of radius a , and prove that its area is one-fourth of the circumscribed triangle.

(b) Find the radius of a circle having an area equal to that included between two concentric circles of 330 and 440 inches in circumference, respectively.

WORLD'S HISTORY.

I. (a) What were the causes and results of the late Russo-Japanese War? Give the period of time covered, and mention one important naval battle of this war.

(b) Explain briefly the following references: (1) The Commune of Paris; (2) Nihilism.

(c) Tell about (1) the battle of Salamis; (2) the battle of Trafalgar.

II. (a) What year marks the end of the Middle Ages and the beginning of the Modern Era? What were the signs of activity at this time?

(b) Tell very briefly of the rise of the Saracens.

(c) What was the Hanseatic League? When and why was it formed?

III. (a) Tell about the Six Weeks' War.

(b) Give the period of time covered by the reign of Queen Elizabeth and the general character of that age.

(c) What great war was fought in 1877-78? What was the general result of that war?

IV. (a) In what did chivalry have its origin? When did it become a regular system? What were the effects of chivalry?

(b) (1) It is said that Rome still governs the world. In what respect is this true? (2) What were the Wars of the Roses?

(c) Explain briefly the following references: (1) The Invincible Armada; (2) Ashburton Treaty.

V. Tell when and where each of the following lived and what he is famous for: (1) Wolsey; (2) Marlborough; (3) Victor Hugo; (4) Darwin; (5) Diogenes; (6) Kossuth; (7) Goethe; (8) Agassiz; (9) Lincoln; (10) Mozart.

ARITHMETIC.

Time allowed two hours.

N. B.—In solving problems the processes should be not merely indicated, but *all the figures necessary* in solving each problem should be *given in full*. Number the work and answers to correspond with the numbers of the questions. The answer to each problem should be indicated by writing "Ans." after it.

N. B.—Do not write on this sheet. Blank sheets will be furnished for the answers to the questions hereon. Number answers to correspond with numbers of questions.

Write only on the ruled side of the blank sheets furnished.

Do not use a separate sheet of any kind for rough work. All work should be submitted in its original form. No smooth copy is required. Pencil may be used for all mathematical work.

Question 1. (a) Find the G. C. D. of 125543 and 1454762.

(b) What decimal part of 38464 is 122.41168?

(c) Simplify $\frac{(\frac{1}{2}-\frac{1}{3}) \times 5\frac{1}{2}}{14\frac{1}{2} \times \frac{1}{2} - \frac{1}{21}} + \frac{1\frac{1}{2} + \frac{1}{2}}{\frac{1}{4} - \frac{1}{2}}$.

Question 2. (a) How long will it take to walk around a square field containing 13 acres and 81 square yards, at the rate of $3\frac{1}{2}$ miles per hour?

(b) How many miles per hour are made by a locomotive having driving wheels 6 feet 3 inches in diameter and making 110 revolutions per minute? ($\pi=3.1416$.)

Question 3. (a) Find the value to six decimals of $\frac{3+\sqrt{7}}{3-7}$.

(b) If 2,000 bolts 1 inch in diameter and 1 inch long are cast from a cubic foot of molten metal, what was the linear shrinkage in inches (to three decimal places)? ($\pi=3.1416$.)

Question 4. (a) A man agrees to exchange a note for \$2,000 for 1 year and 3 months at 6 per cent simple interest, for a note at 5 per cent yielding the same returns. What must be the face value of the new note?

(b) If the ratio of the volume of water to ice is 1 to 1.089, how many gallons of water in a sheet of ice 330 feet by 278 feet and $5\frac{1}{2}$ inches thick, if there are 1,000 ounces in a cubic foot and $1\frac{1}{2}$ pounds in a pint?

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Question 5. (a) Find the number of feet in $\frac{1}{4}$ sea mile, i. e., $\frac{1}{4}$ of the earth's equator, if the diameter of the earth is 7,925 miles and $\pi=3.1416$. What is the length in feet of $\frac{1}{4}$?

(b) A number of articles were bought for a sum of money, and 25 per cent added for freight. If one-fourth of the articles were broken and the remainder sold at an advance of 50 per cent for each, what per cent is lost or gained?

The following is a list of the books covering the above subjects. They are the best to use in preparation for the examination:

Complete Geography, by A. E. Fry.

The Student's American History, by D. H. Montgomery.

Advanced Arithmetic, by G. A. Wentworth.

Wentworth's Elementary Algebra.

Robbins's Plane Geometry.

Any good grammar obtainable.

EXAMINATION FOR MACHINIST, U. S. N.

The following is the written examination used in 1914 for candidates for appointment as machinist, United States Navy:

HANDWRITING AND COMPOSITION—VALUE, 5.

1. Write a letter to the board giving—
 1. Your name in full.
 2. The date and place of your birth.
 3. If a naturalized citizen of the United States, give date and place of naturalization.
 4. A brief history of your engineering experience, both in civil life and in the United States Navy.
 5. What position you are an applicant for, and your reasons for thinking yourself qualified to fill it.

ARITHMETIC—VALUE, 10.

1. How many inches are there in $\frac{7}{16}$ of a foot?
2. Perform the following subtractions:

$$\frac{3}{7} - \frac{1}{24}, \frac{17}{15} - \frac{6}{25}, \frac{17}{64} - \frac{1}{4}, \frac{813}{288} - \frac{13}{16}.$$

3. Six tons of coal are burned in 12 hours on a grate 6 feet long by 7 feet wide. What is the rate of combustion of coal per hour in pounds per square foot of grate surface?

4. Coal bunker 24 feet long, 12 feet wide, and $17\frac{1}{2}$ feet high, has running through it a coaling trunk 3 feet by 2 feet by $17\frac{1}{2}$ feet and also a pipe 32 inches outside diameter by 12 feet long. How many tons of coal will this bunker hold when coal is trimmed evenly to within 6 inches of the top if 42 cubic feet of coal is a ton?
5. Multiply $\frac{3}{4}$ by $\frac{1}{16}$, and divide the result by $\frac{1}{4}$.

ENGINES AND BOILERS—VALUE, 25.

(NOTE.—Where descriptions are called for, due weight will be given for sketches which make the explanations clearer.)

1. Describe a water-tube boiler and give list of all of its external and internal fittings. Describe in detail the method of cutting out a tube and putting in a new one.
 2. (a) What is saturated steam?
 - (b) What is superheated steam?
 - (c) How is superheated steam obtained in a boiler designed to produce it?
 - (d) What are the advantages and disadvantages in the use of superheated steam?
 - (e) What is meant by wire drawing as applied to steam?
3. (a) What causes natural draft in a smoke pipe?
- (b) What is forced draft and how is the strength of it measured?
- (c) Of what use is an analysis of smoke-stack gases?
4. You are in charge of a four-cylinder triple-expansion engine and this engine has broken a high-pressure connecting rod; you decide to run with the other cylinders. State how you would proceed, air and circulating pumps independent.
5. State the various inspections and methods taken for the care and preservation of boilers. Discuss fully corrosion, test of feed water, and use of boiler compound.
6. (a) How test a steam gauge?
- (b) Why is a loop always placed in a steam pipe leading to a gauge?
- (c) How keep a main condenser from becoming air bound?
7. In a triple-expansion engine the intermediate crank pin is running warm. How would you reduce the load on this pin without slowing down the engine? What effect would this have on the travel of the valve? On the lead of the valve? On the cut-off?
8. Describe, in natural order, all the steps you would take to thoroughly clean a water-tube main boiler. Boiler is cold after long trip at sea. Name all the tools and appliances used in cleaning. (Babcock & Wilcox boiler preferred.)

9. Give your idea of a set of general rules for efficient firing of water-tube boilers.

10. Describe a thrust block generally fitted to reciprocating engines and state how you tell that it is properly adjusted. Or, explain how the clearances of a turbine are measured and how the rotor is adjusted.

11. (a) What is the effect of an excess of air in the furnaces?

(b) In what ways may this air enter?

(c) How may it be properly regulated?

(d) Why are fires sliced?

(e) Why are they raked?

12. Give a brief description of a Parsons marine steam turbine, and tell how reversal of motion is effected.

13. Explain how to refit a set of crank-pin brasses of a large engine. How close would you set them up, and how would you measure the distance?

14. (a) How test a main condenser installed in connection with—

(1) A reciprocating engine?

(2) A turbine?

(b) Describe in detail the process of retubing a main condenser.

15. One of the following required:

(1) Describe fully the forced lubrication system on a reciprocating engine of turbine.

(2) Describe a system of burning fuel oil in use in the Navy.

(3) A twin-screw battleship with reciprocating engines and water-tube boilers is at anchor with steam on two boilers; other boilers full of water. Orders given to be ready to get underway in six hours with steam on all boilers natural draft. Describe in detail and in natural order everything done from the time the order is given until the ship is steaming at full power natural draft.

AUXILIARIES—VALUE, 12.

1. Describe any form of ash expeller or ash ejector, and explain how it operates.

2. What pressures should be carried for best operation in—

(a) Coil of high-pressure evaporator in a double-effect plant?

(b) Shell of high-pressure evaporator in a double-effect plant?

(c) Coil of low-pressure evaporator in a double-effect plant?

(d) Shell of low-pressure evaporator in a double-effect plant?

(e) Compressor cylinder of a dense-air ice machine?

(f) Expander cylinder of a dense-air ice machine?

(g) Auxiliary exhaust line discharging into a main feed water heater located on suction side of feed pump?

(h) Auxiliary exhaust line discharging into a main feed water heater located on discharge side of feed pump?

3. What troubles are apt to occur with steam-launch machinery, and how are they avoided?

4. (a) Describe a two-cycle or a four-cycle gasoline engine.

(b) What is the function of a carburetor?

(c) What is meant by the mixture being too rich, and how is this condition discovered?

5. Give a list of the pumps in the engineer department of a vessel, with their connections.

6. Make a line sketch of an evaporating plant operating in double effect, and give a brief description of same.

7. (a) What is the purpose of steam traps?

(b) Where are traps fitted?

(c) What type do you consider the best, and why?

(d) What is the purpose of a pressure-reducing valve?

(e) Where are reducing valves generally fitted?

(f) What type do you consider the best, and why?

ENGINEERING INSTRUCTIONS—VALUE, 6.

1. (a) What tests of safety valves are required to keep them in proper operating condition at all times?

(b) What are the requirements of good practice in regard to the care and preservation of coal bunkers and fuel-oil compartments, and the precautions to be taken before entering coal bunkers, oil compartments, and double-bottom compartments.

2. From your experience, what rules would you lay down regarding the examination, test, care, etc., of the following:

Cylinders, receivers, steam jackets.

Piston rings, followers, and follower bolts.

Filters and grease extractors.

Holding-down bolts.

Surface condensers.

Air and circulating pumps.

3. If you were in charge of the engineer department of a naval vessel, what general rules would you make in regard to the following:

(a) Use of forced draft with water-tube boilers.

(b) Handling fires.

(c) Feeding boilers.

(d) Water-pressure tests of boilers.

(e) Condition of idle boilers.

TOOLS, SHOP PRACTICE, REPAIRS—VALUE, 20.

1. (a) Name the attachments of a lathe and tell what each is used for. Name all forms of lathe tools that you know.

(b) What is meant by water finish? Oil finish?

(c) How are cutting tools hardened?

(d) Describe how a taper is cut on a shaft.

2. (a) Describe a boring bar and tell how you set it up and start boring out the main high-pressure cylinder.

(b) Describe how you would lay off and cut a spur-gear wheel, with the facilities usually supplied on a large naval vessel.

3. (a) Describe how you would repair a split in a copper auxiliary exhaust line, naming the tools used.

(b) Describe the process of applying the protective coating used on the inside of copper pipes intended for salt water.

4. Describe the molding and casting of a 6-inch composition lift check valve.

5. (a) Name the tools used by a boiler maker.

(b) In Babcock & Wilcox boilers where are taper rolls used in a tube expander? Where are straight rolls used?

6. Describe in detail how you would remove a piston rod from the main engines of a battleship; take a smooth cut over its surface, and replace same. State all tools and appliances required, cutting tools used, and the number of men required.

7. Describe in detail how you would rebore the water cylinder of a main feed pump, with pump in place. Give all tools and appliances required and how they are used.

8. (a) Explain in detail how to straighten a bent shaft of a 50-foot steamer.

(b) What are the following metals and where are they used in the engineering department on board ship:

1. Brass.

2. Tobin bronze.

3. Monel metal.

4. Babbitt metal.

5. Russian iron.

6. Cast iron.

7. Wrought iron.

8. Forged steel.

9. Explain how you would balance the rotor of a steam turbine used for driving auxiliaries, such as dynamos, blowers, etc.

10. How would you balance a blower that appeared to vibrate excessively?

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INDICATORS AND SCREW PROPELLERS—VALUE, 8.

1. (a) How is the power developed by the engine measured, and in what units is it expressed in the following:

1. A reciprocating engine?

2. A turbine?

3. A gasoline engine?

(b) Draw the outline of a typical indicator card from one end of a cylinder, and indicate the following:

1. Admission line.

2. Expansion line.

3. Exhaust line.

4. Atmospheric line.

5. Compression line.

6. Point of cut-off.

2. What is meant by—

(a) The water rate (or water consumption) of an engine?

(b) The statement that a certain vessel uses 1.5 pounds of coal per indicated horsepower per hour?

(c) The ratio of expansion of an engine?

(d) The cylinder ratio?

3. What information as to faults can be obtained from an indicator card? Give sketches of cards in each case.

4. A ship with a propeller of 19-foot pitch is making 60 revolutions per minute and is making exactly 10 knots through the water. Calculate the slip of the propeller (6,080 feet equals 1 knot).

5. Describe how you would alter the pitch of a three-bladed built-up propeller as fitted to naval vessels. Show by rough sketches how the propeller bolts are prevented from backing out.

DRAWINGS AND SKETCHES—VALUE, 10.

1. Sketch one of the following:

(a) Feed-water heater.

(b) Any water-tube (main) boilers.

(c) Evaporator.

(d) Loose coupling on forward end of stern-tube shaft of main engine.

2. Sketch one of the following:

(a) In one-half size, an eccentric sheave keyed to a shaft with 20° angular advance; shaft 5 inches in diameter; sheave with 3 inches eccentricity.

(b) A horseshoe-thrust collar and a main bearing brass, showing oil holes and grooves.

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STORES AND SPARE PARTS—VALUE 4.

1. Make a list of packing used on your last ship, and state where each was used.
2. Give a list of small spare parts usually carried for—
 - (a) Steam launch engines.
 - (b) Reducing valves.
 - (c) Main feed pumps.
 - (d) Dense-air ice machines.
 - (e) Main condensers.
3. Give a list of all materials, not metallic, used on a main boiler and main steam line.

SUGGESTIONS.

The following points, if observed, will be of assistance to an applicant taking this examination:

1. The examination in handwriting and composition is practically the same every year. The form of the letter should be as follows:

NAVY YARD, NEW YORK,
November 15, 1915.

From: John P. Brown, chief machinist's mate, United States Navy.

To: Examining board.

Subject: Statement of applicant for appointment as machinist, United States Navy.

1. My name is John Paul Brown.
2. I was born at Albany, New York, on September 18, 1883.
3. I am not a naturalized citizen of the United States.
4. In July, 1901, I began an apprenticeship to the machinist's trade in the employ of J. Mud & Co., Bridgeport, Connecticut, and was so employed until July, 1904, when I completed my apprenticeship and was given a certificate.

From July, 1904, to September, 1907, I served as a machinist in the employ of the following firms: J. Mud & Co., Bridgeport, Connecticut; Fore River Shipbuilding Company, Quincy, Massachusetts; and Atlantic Repair Co., East Boston, Massachusetts. During this time I gained experience in the operation of nearly all kinds of machine tools, the erection and repair of marine engine installations, and the running of trial trips.

On September 18, 1907, I enlisted in the Navy as a machinist's mate, second class, and have served on the following ships: The

Iowa, the *Vermont*, the *Beale*, and the *Arkansas*, and have had experience on all the stations on board ship.

I have had seven years' service on board cruising vessels, and have held the rate of chief machinist's mate since January 1, 1912.

5. I am an applicant for appointment as machinist, United States Navy, and think myself qualified to fill this position because of my experience as a machinist, my service in the Navy, and my ability to handle men.

JOHN P. BROWN.

2. Before answering any question read it carefully and be sure to copy it correctly and avoid misspelling words. In the examination in 1914 many applicants misspelled "machinist."

3. Do not answer more than the question calls for, and, wherever possible, in case a list is called for, tabulate the list. For example:

External fittings of a boiler—

Safety valve.

Air cock.

Pressure-gauge connection.

Steam-stop valve.

Main feed stop and check valves.

Auxiliary feed stop and check valves.

Try cocks.

Gauge-glass fittings.

Surface blow valves.

Bottom blow valves.

Drain valve.

Sampling cock for drawing water for test.



